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1919.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, Burlington House, London, W., June 18, 1918, *at* 5 *p.m.*

Mr. W. Barlow, F.R.S., President, in the Chair.

The following changes in the list of Officers and Council were approved for recommendation to the Members of the Society: President—Sir William P. Beale, in place of Mr. Barlow; Treasurer, Dr. J. W. Evans, in place of Sir William P. Beale; Ordinary Members of Council—Sir Jethro J. H. Teall, Messrs. Holmes and Rastall, and Miss Porter, in place of the four retiring Members of Council, Messrs. Barker, Barrow, Cullis, and Mennell.

GENERAL MEETING.

Held in the Apartments of the Geological Society, Burlington House, London, W., June 18, 1918, *at* 5.30 *p.m.*

Mr. W. Barlow, F.R.S., President, in the Chair.

Fifteen Members and one Visitor were present.

The following papers were read:—

1. On the origin of septaria: by Mr. W. A. Richardson (p. 327).
2. The composition of the nickeliferous iron of the meteorites of Lodran, Powder Mill Creek, and Holbrook: by Dr. G. T. Prior.

Specimens of septarian nodules and lantern-slides were exhibited by Mr. Richardson in illustration of his paper.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, Burlington House, London, W., November 5, 1918, *at* 5 *p.m.*

Sir WILLIAM P. BEALE in the Chair.

The death of Mr. J. S. Merry was reported.

Mr. William Howson Wilcockson, Mr. Arthur Stanley Williams, and Lieut. Arthur Broughton Edge were provisionally elected Ordinary Members of the Society.

The following were selected as the dates of the meetings in 1919: Tuesdays, January 14, March 18, June 17, November 4 (Anniversary).

The draft Annual Report of Council, submitted by the Secretary, was read and approved.

Mr. Barlow was reappointed to represent the Society on the Conjoint Board of Scientific Societies for 1919.

A vote of thanks was passed to Dr. G. F. Herbert Smith for sending notices of the meetings of the Society to 'Nature' and other periodicals.

ANNIVERSARY MEETING.

Held in the Apartments of the Geological Society, Burlington House, London, W., November 5, 1918, *at* 5.30 *p.m.*

Sir WILLIAM P. BEALE, President-elect, in the Chair.

Sixteen Members and one Visitor were present.

The Chairman nominated Messrs. Gordon and Hilton to act as scrutineers of the voting-papers for the election of Officers and Council. The scrutineers reported that twenty-nine voting-papers had been returned to the Secretary, and that the list as nominated by the Council was approved, namely:—

President. Sir William P. Beale, Bart., K.C., M.P., F.G.S., F.C.S.

Vice-Presidents. Prof. H. L. Bowman, M.A., D.Sc., F.G.S.
A. Hutchinson, M.A., Ph.D., F.G.S.

Treasurer. J. W. Evans, LL.B., D.Sc., F.G.S.

General Secretary. G. T. Prior, M.A., D.Sc., F.R.S.

Foreign Secretary. Prof. W. W. Watts, LL.D., Sc.D., F.R.S.

Editor of the Journal. L. J. Spencer, M.A., F.G.S.

Ordinary Members of Council.

H. Collingridge, B.Sc., F.G.S.
T. Crook, F.G.S.
G. F. Herbert Smith, M.A., D.Sc., F.G.S.
H. H. Thomas, M.A., Sc.D., F.G.S.
H. F. Collins, A.R.S.M., M.I.M.M.
J. P. De Castro, M.A., F.C.S.
Prof. H. Hilton, M.A., D.Sc.
Lieut. Arthur Russell.
A. Holmes, D.Sc., F.G.S.
Miss M. W. Porter.
R. H. Rastall, M.A., F.G.S.
Sir Jethro J. H. Teall, M.A., D.Sc., LL.D., F.R.S.

The elections of Mr. W. H. Wilcockson, Mr. A. Stanley Williams, and Lieut. A. B. Edge as Ordinary Members of the Society were confirmed.

The following Annual Report of Council was read:—

During the Session 1917–18 four ordinary meetings have been held (by kind permission) in the Apartments of the Geological Society, Burlington House, W., at which eleven papers were read. A special meeting of the Council was held on January 7, 1918, at the Natural History Museum, at which a resolution was passed protesting against the proposal to make use of the Natural History Museum for other Government Departments. One number of the Journal containing seven papers has been issued, viz. No. 85, published in August 1918.

The balance-sheet of the year ending December 31, 1917, shows that the financial position of the Society continues to be satisfactory. The assets (exclusive of the Library and stock of the Journal) amounted to £924 6*s.* 10*d.*, and the liabilities to £15 11*s.* 10*d.* The value of the Stock invested in the names of the Trustees of the Society was on that date £795 0*s.* 0*d.*, corresponding to £16 11*s.* 3*d.* for each Life-Member.

During the Session the death of one Life-Member, Mr. J. S. Merry, has been reported. Two Ordinary Members have been elected. The total number of Members on November 4, 1918, was 134, of whom fifteen are Honorary. Of the Ordinary Members forty-eight are Life-Members.

The Council has to congratulate the Society on its continued scientific activity and prosperity during the war.

On the motion of Dr. J. W. Evans, seconded by Dr. A. P. Young, the Report was adopted.

A vote of thanks to the Council of the Geological Society for permission to meet in the Apartments of the Society was carried.

The dates of meeting for 1919, proposed by the Council, were approved.

The following papers were then read:—

1. On a plagionite-like mineral from Dumfriesshire: by Dr. G. F. Herbert Smith and Dr. G. T. Prior.

2. The chromite deposits in the island of Unst, Shetlands: by Lieut. Arthur Russell.

3. The nickeliferous iron of the meteorites of Bluff, Chandakapur, Château Renard, Cynthiana, Dhurmsala, Eli Elwah, Gnadenfrei, Kakowa, Lundsgård, New Concord, Shelburne, and Shytal: by Dr. G. T. Prior.

Specimens of the plagionite-like mineral were exhibited by Dr. Herbert Smith, and a fine series of minerals from Unst by Lieut. Russell.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, Burlington House, London, W., January 14, 1919, *at* 5 *p.m.*

Mr. W. Barlow, F.R.S., Past-President, in the Chair.

Lieut. William Argus McIntyre, Lieut. George Sheppard, and Mr. Richard Hansford Worth were provisionally elected Ordinary Members of the Society.

Messrs. F. H. Butler and T. Crook were elected Auditors of the accounts for the year ending December 31, 1918.

GENERAL MEETING.

Held in the Apartments of the Geological Society, Burlington House, London, W., January 14, 1919, *at* 5.30 *p.m.*

Mr. W. Barlow, F.R.S., Past-President, in the Chair.

Sixteen Members and two Visitors were present.

The elections of Lieut. W. A. McIntyre, Lieut. G. Sheppard, and Mr. R. H. Worth as Ordinary Members of the Society were confirmed.

A demonstration was given by Mr. A. Hutchinson on stereoscopic lantern slides of crystal pictures; and the following paper was read:—

Mineralogical characters of turite (= turgite) and some other iron-ores from Nova Scotia: by Mr. L. J. Spencer (p. 339).

THE MINERALOGICAL MAGAZINE

AND

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THE MINERALOGICAL SOCIETY.

No. 86. May, 1919. Vol. XVIII.

On Sartorite and the problem of its crystal-form.

By G. F. Herbert Smith, M.A., D.Sc., F.G.S.

Assistant in the Mineral Department of the British Museum,[1]

and R. H. Solly, M.A.

[Read June 16, 1914, and June 19, 1917.[2]]

TO mineralogists probably few spots in the world surpass in interest the little quarry[3] hollowed out of the dolomite, just where the latter is cut by the Lengenbach, and about half a kilometre above the point where this stream ends its hurried course by joining the Binna at Imfeld, a hamlet lying in the main valley three kilometres above the village of Binn. Here within the compass of a few square metres have

[1] Communicated by permission of the Trustees of the British Museum.

[2] The following were the papers read before the Society: 'On sartorite,' by R. H. Solly, June 16, 1914, and 'On the problem of sartorite,' by G. F. Herbert Smith, June 19, 1917.

[3] An interesting description of the quarry, including an account of its history, is given by Léon Desbuissons in 'La Vallée de Binn (Valais),' Lausanne, 1909, Georges Bridel & Cie, pp. 60–67, some of the particulars being supplied by R. H. Solly.

been found an abundance of well-crystallized mineral-species,[1] not a few of which are peculiar to the quarry, and as yet not known to occur elsewhere. Although of the lead-grey, metallic minerals found here the commonest has been the one considered in this paper, so rare are crystals sufficiently well developed and with sufficiently smooth faces for goniometrical measurement that the precise nature of the crystallization of this species has even up till now been in doubt. The authors have between them had the opportunity of studying a large number of crystals, and among them a few with measurable pyramidal faces. They have therefore been enabled to determine definitely the zonal characters of the crystals, and thereby to arrive at two conclusions:—In the first place, sartorite appears to rank with the telluride of gold—calaverite[2]—in the peculiarity of its atomic arrangement, since in certain at least of its crystals there exist simultaneously two or even three incongruent space-lattices, which may be supposed derivable from one another by a slight shear. In the second place, the mineral represented by the two crystals figured and described by Trechmann[3] is not the same as that defined by vom Rath, although without doubt closely allied to it; it is therefore in this paper for distinction called sartorite-α.

I. Historical.

Careful investigation has established the existence of upwards of ten different species among the lead-grey, metallic minerals occurring in or around the Binn Valley, but so closely do they to a casual, and even, in many instances, to a careful inspection resemble one another that in

[1] Altogether upwards of twenty-five mineral species have been described from the Lengenbach quarry. The most interesting of them are jordanite, tennantite (binnite), and hamlinite (bowmanite), and those peculiar to the quarry, viz. sartorite, seligmannite, baumhauerite, rathite, dufrenoysite, lengenbachite, liveingite, marrite, and hatchite, which are black and opaque, and hyalophane, smithite, hutchinsonite, and trechmannite, which are transparent, the first being colourless and the remainder red.

[2] G. F. Herbert Smith, On the remarkable problem presented by the crystalline development of calaverite. Mineralogical Magazine, 1902, vol. xiii, pp. 122–150.

[3] C. O. Trechmann, Crystallography of sartorite from Binn. Mineralogical Magazine, 1907, vol. xiv, pp. 212-229. It is evident from the concluding paragraphs of his paper that he fully realized the uncertainty of the identity with sartorite of the crystals numbered by him 1 and 2. After pointing out that the character of even the smallest pyramidal faces permitted of exact goniometrical measurement he says—'With less confidence would I wish it to be assumed that the crystals Nos. 1 and 2 are, beyond doubt, to be considered as sartorites.'

early days, as it is not surprising to learn, they were all confused together apparently as tetrahedrite, to judge from what appears to be the earliest recorded reference[1] to these minerals. Even a few years later, in 1839, Wiser[2] remarked that the grey, crystalline substance in the dolomite of the Binn Valley was a compound of sulphur-lead with sulphur-antimony, but almost immediately he published a correction,[3] noting that considerable arsenic was present, and little antimony. The following year[4] (1840) he noted the difference in the colour of two examples of these substances. During the succeeding years Swiss collectors had come to use the term binnite to denote the lead-grey minerals from the Binn Valley, differentiating between 'Kugel-Binnit' and 'Stangen-Binnit' according to the spherical or columnar shape of the crystals, and the name found its way into the catalogues of the mineral dealers.[5]

The first considerable investigation of the lead-grey minerals from the Binn Valley was made by Damour.[6] He analysed some poorly crystallized material, and found the composition to correspond to the formula $2PbS.As_2S_3$, and, inasmuch as no mineral with such a composition was at that time known, named it dufrenoysite. He perhaps naturally, but as it turned out wrongly, presumed that a small, brilliant, dodecahedral crystal closely associated with the material analysed was the same species, and accordingly so described the crystal form of his new mineral.

It was not till ten years later, in 1855, that the mistake was pointed out by von Waltershausen,[7] but unhappily in such a way as to leave the confusion almost worse. He remarked that the crystal form of a mineral

[1] C. Lardy, Essai sur la constitution géognostique du St.-Gothard. Denkschriften der allgemeinen Schweizerischen Gesellschaft für die gesammten Naturwissenschaften, 1833, vol. i, pp. 200–280. See p. 244: 'La dolomie de Binden renferme, en outre du Feldspath adulaire, de l'arsenic sulfuré rouge et jaune, du zinc sulfuré jaune en beaux cristaux et une substance métallique d'un gris de plomb qu'on a prétendu être de l'antimoine.'

[2] D. F. Wiser, Beiträge zur mineralogischen Kenntniss des Schweitzerlandes. Neues Jahrbuch Min., 1839, pp. 406–415. See p. 414.

[3] D. F. Wiser, ibid., p. 557.

[4] D. F. Wiser, Neues Jahrbuch Min., 1840, p. 216.

[5] Cf. Annalen der Physik u. Chemie, 1885, vol. xciv, p. 335.

[6] A. Damour, Notice sur le sulfo-arséniure de plomb du Mont Saint-Gothard. Annales de Chimie et de Physique, 1845, 3rd series, vol. xiv, pp. 379–383. Also see l'Inst. 1845, p. 141 ; Compt. Rend. Acad. Sci. Paris, 1845, vol. xx, p. 421.

[7] W. Sartorius von Waltershausen, Ein Beitrag zur näheren Kenntniss des Dolomits in den Walliser Alpen. Annalen der Physik u. Chemie, 1855, vol. xciv, pp. 115–141. See also Sitzb. Akad. Wien, 1854, vol. xiv, p. 291.

with a composition such as that found by Damour would *a priori* have been expected to have been very similar to that of the analogous antimony mineral, feather-ore, which obviously from its characteristic form did not belong to the cubic system. On examining specimens from the Binn Valley, he came to the conclusion that more than one species was represented among the lead-grey minerals, since some of the crystals were monometric, and others trimetric in symmetry. A chemical analysis of the trimetric material which was made by Uhrlaub did not yield simple ratios between the principal constituent elements; a difficulty which von Waltershausen met by supposing that the mineral was an isomorphous mixture of two hypothetical species, the one, which he named arsenomelane, with the constitution $PbS.As_2S_3$, and the other, which on account of its excessive brittleness he named scleroclase,[1] with the constitution $2PbS.As_2S_3$. The latter species had therefore the composition of Damour's dufrenoysite, but presumably differed from it in its crystalline characters. The name dufrenoysite he proposed to retain for the dodecahedral crystals, which were shown on an analysis by Uhrlaub to be a sulpharsenite, not of lead, but of copper. Von Waltershausen illustrates his paper with drawings of two crystals of the material analysed. On one of them—an iron-black crystal—he was able to make a few angular measurements and thence to deduce the crystal elements. By adopting his setting up of the crystals we have as the observed angles:—$(101):(\bar{1}01) = 64° 44'$, $(101):(011) = 45° 1'$, and from them obtain:—$(1\bar{0}0):(101) = 57° 38'$; $(010):(011) = 56° 49'$. These angles do not accord with the accepted values which have been found for any of the principal angles of the known sulpharsenites of lead. The nearest is dufrenoysite, in which $(010):(011) = 56° 56'$; but the agreement in the second corresponding zone is unsatisfactory, the best angle being $(001):(704) = 59° 9\frac{1}{2}'$. It is worth noting that in hutchinsonite,[2] a red-silver mineral found in the Lengenbach quarry, which crystallizes in the orthorhombic system, $(100):(110) = 58\ 32'$, and $(001):(021) = 56° 29'$. The last substance, however, does not occur in iron-black crystals. It is at any rate quite clear, both from the habit of the crystals as shown by the drawings and from the measurements made on

[1] *σκληρός*, hard, *κλάειν*, to break. See loc. cit., p. 126, 'seiner ausserordentlichen Sprödigkeit halber.' The name is not very happily derived; the first of the Greek words has much the same shades of meaning as the Latin *durus*, and the obvious meaning of the word scleroclase would be a substance difficult to break, which is just the opposite to what was intended.

[2] Mineralogical Magazine, 1907, vol. xiv, p. 287.

one of them, that they were not sartorite. The analysis was evidently made on a mixture of the salpharsenites of lead, among which no doubt there was some sartorite.

Heusser,[1] who almost simultaneously with von Waltershausen investigated the lead-grey minerals from the Binn Valley, likewise divided them into two kinds: the one, crystallizing in the regular system, which he also named dufrenoysite, and the other, occurring in the form of heavily furrowed, prismatic crystals, which he proposed to call binnite.[2] He depicts two of the latter crystals, and gives the following measurements in the well-developed dome-zone—58° 6′, 50° 19′, 38° 46′, 21° 56′—which agree with the mean values found for the zone (100):(010) of sartorite (p. 265). He gives a figure also of what he regarded as another crystal of 'binnite', but was unable to measure any of the angles because it was coated with a yellowish-green tarnish. The habit is, however, sufficient to assure us that the crystal was not a sartorite, though we can only conjecture to what species it belonged; it may have been really what we now know as binnite.

In the course of the summer of 1855 Des Cloizeaux and Marignac also visited the Binn Valley, and collected a series of specimens of the minerals occurring there. They collaborated in an investigation of the specimens, and a memoir on the results of their research was published by Des Cloizeaux.[3] Early in it he mentioned that the dodecahedral crystal which had given rise to so much confusion, because Damour had mistakenly supposed that it was identical with the material analysed by him, had by accident been broken, and that on analysis of a fragment thus afforded it turned out to be a sulpharsenite of copper, just as Uhrlaub had found. Remarking that the mistake in the determination of the crystalline form in no way invalidated Damour's discovery of the new mineral, he rightly dissented from the course followed by both von Waltershausen and Heusser of transferring the name dufrenoysite to the copper mineral. When, however, he came to describe the crystalline form of dufrenoysite, Des Cloizeaux was far less happy, because, as was

[1] C. Heusser, Ueber den Dufrenoysit, Binnit und Adular des Binnenthales. Annalen der Physik u. Chemie, 1856, vol. xcvii, pp. 115–129.

[2] C. Heusser, loc. cit. Cf. also ibid., 1855, vol. xciv, pp. 334–335. 'Binnit, ein Name, der in der Schweiz auch bisher statt Dufrenoysit allgemein gebraucht wurde (—man wusste noch Nichts von zwei verschiedenen Schwefelmetallen, sondern glaubte damit den Dufrenoysit des Hrn. Damour zu bezeichnen—) und der ganz passend an den bisher einzigen Fundort erinnert.'

[3] A. L. O. Des Cloizeaux, Sur les formes cristallines de la dufrenoysite. Annales des Mines, 1855, 5th series, vol. viii, pp. 389–398.

apparent with the aid of knowledge obtained later,[1] Marignac's measurements, which were quoted by Des Cloizeaux, had really been made on crystals of sartorite, and the crystals represented by figs. 1 and 2 belonged to that species, while the two small crystals depicted in figs. 3, 3a, and 4 belonged to yet another species—jordanite. As was pointed out by Solly,[2] had Des Cloizeaux tested the specific gravity or at least tried the streak he would at once have seen that his material consisted of at least two distinct species, because jordanite is much denser than sartorite and dufrenoysite, and has a black streak, whereas that of the other two minerals is chocolate-brown in colour.

For a considerable advance in our knowledge of these complexly intergrown metallic minerals from the Binn Valley we have to thank vom Rath. By means of a careful goniometric examination of the non-cubic, metallic material he was enabled to distinguish three distinct species, viz. dufrenoysite, scleroclase, and jordanite, of which the last-named was new. The first and third of them do not concern our present purpose. Under the name scleroclase he described small, needle-shaped, prismatic crystals, which were heavily striated and grooved parallel to their length, and remarked that the mineral was the same as Heusser's binnite and von Waltershausen's scleroclase.[3] He observed the following series of angles measured from the cleavage-face in the prism- and dome-zones,[4] which are mutually at right angles. He regarded the symmetry as orthorhombic. The indices of the faces quoted in the table are vom Rath's, but the angles are the supplements of those given by him, it being the custom in his day to give the obtuse angles between the faces of crystals.

[1] Cf. G. vom Rath, Annalen der Physik u. Chemie, 1864, vol. cxxii, p. 373.

[2] R. H. Solly, Mineralogical Magazine, 1900, vol. xii, p. 283.

[3] As was pointed out above (p. 262) von Waltershausen's hypothetical species had the composition of dufrenoysite; no doubt some of his material was sartorite.

[4] Throughout the present paper the authors use the term 'prism' for the striated zone the edge of which is parallel to the length of the crystal, and the term 'dome' for the, when present, generally broad and well-developed zone running over the end of the crystal. Since, as will be seen below (p. 307), the symmetry is really monoclinic with the plane of symmetry at right angles to the length of the crystals, the terms should, if to accord with the old convention, be interchanged.

Table I. Angular distances from the cleavage-face observed by vom Rath.

Form.[1]	Dome-Zone.	Form.	Prism-Zone.
Be 011	31°45′	5·0·14	22°30′
Bd 043	39 30	5·0·11	28 24
Bx 032	43 28	509	32 30
Bc 021	51 10	101	49 45
Bb 041	67 58	503	62 0
		10·0·1	85 2

ne, but only one, of his crystals, viz., that illustrated in his fig. 3, owed the only pyramidal form observed, the one which he selected as 11). Its position was determined by the angle (011) : (111)=44° 19′, hence may be calculated its distance from the cleavage-face, 52° 31½′, nd its azimuth from the prism-zone, 28° 19′; it is therefore the form alled *Px* below (p. 295).

The name which in this paper we have used for the mineral was pro-osed in 1868 by Dana,[2] who rejected the name scleroclase for the following eason:—'As the name scleroclase is inapplicable, and the mineral was first nnounced by Sartorius v. Waltershausen, the species may be appro-riately called Sartorite.' It is not clear what was his precise meaning; e may possibly have discarded the name scleroclase on account of its un-uitability on etymological grounds (cf. above p. 262), and because it was riginally used by von Waltershausen for a species with the composition f dufrenoysite.

Thirty years passed by before any addition was made to the founda-ion laid by vom Rath, and it was not till 1895 that Baumhauer[3] pub-ished the results of his investigation of the goniometric properties of our crystals of sartorite from the Binn Valley. He, like vom Rath, egarded the symmetry as orthorhombic, and he adopted the latter's lements for the crystals. The first crystal was small, only 1 mm. across t the widest, the second was a mere fragment, the third measured mm. in length by 1 mm. in breadth, and the fourth was 2 mm. in ength and 2 by 1 mm. in cross-section; the last was developed at both nds. The most interesting crystal was the third, because it displayed

[1] For convenience of reference the forms are lettered in accordance with the otation adopted in this paper (p. 274).

[2] J. D. Dana, System of Mineralogy, 5th edit., 1868, p. 88.

[3] H. Baumhauer, Über den Skleroklas von Binn, Sitzungsber. k. preuss. Akad. Viss. Berlin, 1895, pp. 243-252.

several new pyramidal forms. The indices of the forms in the following table are those given by him. The startling irrationality of some of them is noticeable.

Table II. Angular distances from the cleavage-face observed by Baumhauer.

Crystal 1.

Form.	Angle.
Bf 045	26° 10½′
Bd 043	39 22
Bc 021	50 55
Bb 041	67 58
Ba 010	90 0

Crystal 2.

Form.	Angle.
106	10° 50′
207	18 17½

Crystal 3.

Form.	Angle.
025	13° 38½′
Be 011	31 31½
Bd 043	39 19½
Bc 021	51 6¾
Bb 041	68 1
Px′ 441	79 8½
,, ,,	79 5
Pw′ 221	69 2
104	15 35
3.0.10	18 51
102	30 22
102	30 0½
11.0.4	72 17
Ix′ 20.36.15	64 49½
Iz′ 65.117.9	84 52
Iz 593	69 42½
Iy 85.153.90	56 45½
Ha 174.377.65	77 59½
Hb′ 6.13.1	84 35½
Hc′ 18.39.13	68 8
Hd′ 102.221.90	54 33½
Hc 18.39.26	50 22½

Crystal 4.

Form.	Angle.
106	10° 32½′
104	16 2
207	18 17
3.0.10	18 51
3.0.8	23 35½
509	32 30½
405	42 31½
506	43 39
17.0.18	47 23
26.0.27	47 59
101	48 53
19.0.18	50 28½
,,	50 35
16.0.9	63 41½
0.4.11	12 42
025	14 2
0.9.20	15 29½
012	17 16
,,	16 57½
047	19 30
Bg 023	22 12½
Bf 045	26 20
Bd 043	39 30
0.41.30	40 15½
0.47.30	44 18½
0.17.10	46 32½
0.26.15	47 6
0.29.15	50 3
,,	50 6½
Bc 021	51 8½
Bb 041	67 58½
,, ,,	68 2½
0.7.15	16 5
Bg 023	22 24½
Bf 056	27 5½
0.14.15	30 0½
Be 021	51 8½
,, ,,	51 12½
Bb 041	68 6
,, ,,	68 14½

For fixing the azimuths of the pyramidal zones on crystal 3 the following cross-measurements were made:—$(44\bar{1}) : (021) = 75^{c}\ 53'$, $(20.36.15) : (02\bar{1}) = 77^{\circ}\ 9\frac{3}{4}'$, $(174.377.65) : (021) = 44^{\circ}\ 45\frac{1}{2}'$. By calculation the corresponding aximuthal angles may be obtained; they are respectively 28° 17′, 43° 59′, 49° 34′, measured from the prism-zone.

R. H. Solly[1] spent the summer of 1898 at the Binn Valley, and succeeded in collecting among other minerals a large number of sartorites. After the crystals had been measured on a goniometer, certain of them were picked out for chemical analysis, which was undertaken by H. Jackson.[2] Altogether he made three analyses, the first on small, brilliant crystals, and the other two on larger crystals: the percentages obtained agree very closely, as will be seen from the Table below, with

[1] R. H. Solly, Sulpharsenites of lead from the Binnenthal. With analyses by H. Jackson. Mineralogical Magazine, 1900, vol. xii, pp. 282–297.

[2] R. H. Solly, loc. cit., pp. 286, 287, 289.

those required by the formula $PbS.As_2S_3$. The density, as determined on the best crystals, was 4·980. Solly announced that the symmetry of sartorite is monoclinic, and not orthorhombic as stated by previous observers, but gave no further particulars of the crystals.[1]

Table III. Chemical Analyses of Sartorite by H. Jackson.

	1.	2.	3.	Calc.
Pb ...	43·24	43·93	43·72	42·68
S ...	25·81	24·60	25·12	26·39
As ..	30·80	30·46	30·12	30·93
	99·85	98·99	98·96	100·00

Four years later, in 1902, Baumhauer[2] mentioned that he had obtained some loose crystals, 3 cm. in length, which were probably sartorite.

At the meeting of the Mineralogical Society on March 24, 1903, Lewis[3] exhibited a large crystal of a sulpharsenite of lead, measuring as much as $4 \times 1 \times \frac{1}{3}$ inches ($10 \times 2{\cdot}5 \times 0{\cdot}8$ cm.), which was analysed by H. Jackson, and shown to be sartorite; the figures of the analysis are :—Pb, 42·93; S, 25·32; As, 31·11: total, 99·36.

Again, at the anniversary meeting of the Society in the same year R. H. Solly[4] described specimens of sartorite as well as of other minerals from the Binn Valley.

The following year, 1904, Baumhauer,[5] in the course of a paper dealing with the development of zones rich in faces, gives further measurements made in the prism-zone of sartorite.

In August 1904, C. O. Trechmann visited the Binn Valley, and had

[1] R. H. Solly, loc. cit., p. 297.

[2] H. Baumhauer, Eclogae geol. Helvetiae, 1902, vol. vii, pp. 352-353.

[3] W. J. Lewis, A large crystal of sulpharsenite of lead from the Binnenthal. Mineralogical Magazine, 1903, vol. xiii, p. xxxiv.

[4] R. H. Solly, On sartorite, anatase, galena, and other minerals from the Binnenthal. Mineralogical Magazine, 1904, vol. xiv, p. xx. Abstract in 'Nature', 1903, vol. lxix, p. 142 :—'. . . On fine brilliant crystals of sartorite recently obtained by the author he has been able to confirm the oblique symmetry which he had previously announced, and to determine accurately the elements, $\beta = 88° 31'$, (100) (101) = 54° 45', (010) (111) = 69° 52½' . . .' The last two angles appear, however, to have been incorrectly transcribed.

[5] H. Baumhauer, Über die Aufeinanderfolge und die gegenseitigen Beziehungen der Krystallformen in flächenreichen Zonen. Sitzungsber. k. preuss. Akad. Wiss. Berlin, 1904, pp. 543-554. See also Eclogae geol. Helv., 1906, vol. viii, pp. 582-583.

the good fortune to acquire several good crystals of a sulpharsenite of lead, which he subsequently described.[1] He mentioned seven crystals, but devoted nearly the whole of his memoir to those numbered 1 and 2; of these he gave drawings. Their symmetry he found to be monoclinic. The angles measured in the dome-zone agreed closely with those recorded by vom Rath and Baumhauer in the corresponding zone of their crystals, but in other zones there was complete discordance. The principal angles were found to be as follows:—(100):(110) = 51° 16′, (100):(001) = 77° 48′, (100):(101) = 40° 24½′, (100):(10$\bar{1}$) = 53° 25′; while the corresponding angles given by vom Rath were:—(001):(021) = 51° 3½′, (001):(100) = 90° 0′, (001):(101) = 48° 57′. Trechmann's crystals were well developed, and the character of their faces in nearly every instance permitted of a good reading on the goniometer; altogether he observed 87 forms. Crystals 3 and 4 showed the dome-zone well developed and the prism-zone very much striated, but pyramidal faces were entirely absent. The two crystals were joined together 'in an apparently twinned position'.[2] Crystals 5 and 6 were opposite ends of one and the same complete crystal. 'Both of these crystals have a rich development of pyramidal faces, of which forty-five were counted on No. 5 and about thirteen on No. 6. Twin-lamellae were distinctly observable on both crystals, but especially on No. 6, where some of the faces were devoid of them, and others were closely intersected. The zonal relations of these pyramidal faces were, however, so indistinct, and most of them were so small, that it has not been possible so far to identify them. Some measurements made on crystal No. 6 could not be harmonized with Nos. 1 and 2, nor with the pyramids observed by Baumhauer.'[3] As was pointed out early in this paper (p. 260), he clearly did not feel certain that his crystals 1 and 2 were sartorite. Inasmuch as they cannot be brought into harmony with the mineral defined by vom Rath, they must bear another name, and the authors suggest as such sartorite-*a*.

[1] C. O. Trechmann, Crystallography of sartorite from Binn. Mineralogical Magazine, 1907, vol. xiv, pp. 212–229. The crystals were presented by Dr. Trechmann to the British Museum in 1917, just before his death; those numbered by him 1 and 2 are entered under 390, 3 and 4 under 391, 5 and 6 under 392, and 7 under 393 for the year 1917 in the Register of Accessions in the Mineral Department.

[2] C. O. Trechmann, loc. cit., p. 214. This statement is incorrect. No semi-revolution about any axis will bring the poles of the one crystal into coincidence with those of the other.

[3] C. O. Trechmann, loc. cit., p. 226.

A good summary of what at the time of writing was known of sartorite as well as the other minerals found there was given in 1909 by Desbuissons in his book on the Binn Valley.[1]

The publication of a full description of the crystals of sartorite exhibited at the anniversary meeting of the Mineralogical Society in 1903, which were referred to above, was deferred by Solly in the hopes that additional and better material might be found which would throw light on the puzzling problem presented by this mineral. In 1909, however, the Lengenbach quarry was closed down, and during the years that have since elapsed the disintegrating effect of snow and rain have filled it with huge boulders and tons of drift. The reopening of the quarry would therefore now be such a difficult and costly task that it may be questioned whether any one will be found sufficiently enterprising to undertake it, especially since there were signs that the veins containing the coveted sulpharsenites were fast becoming exhausted. The chance of fresh material coming to light which might be of service in this investigation being thus very remote, Solly, in the course of the years 1913 and 1914, re-measured all the crystals of sartorite that he had obtained before 1903, and in addition measured some good crystals he had acquired since that date. He communicated the results of his investigation to the Mineralogical Society on June 16, 1914.[2] Since some of the crystals showed small pyramidal planes the positions of which could not be determined by means of an ordinary goniometer, Solly brought them to the British Museum for measurement on a three-circle instrument in the Mineral Department. G. F. Herbert Smith undertook the work, and determined the positions of the pyramidal faces on the best crystals. The relations between these faces and the dome-faces were found to be so puzzling and mysterious that it was eventually decided to measure on the three-circle goniometer all the crystals which possessed pyramidal faces, but it was not found possible to prosecute the investigation until the year 1916. Attempts made to bring the observations made on Solly's crystals into harmony with the elements and angles published by Trechmann for his crystals 1 and 2 were entirely without success. It

[1] L. Desbuissons, La Vallée de Binn (Valais). Lausanne, 1909. For sartorite see pp. 104–106.

[2] R. H. Solly, On sartorite. Mineralogical Magazine, 1914, vol. xvii, p. xxxi. Abstract in 'Nature', 1914, vol. xciii, p. 471, 'From a goniometrical examination of 200 crystals it is contended that Dr. Trechmann's crystals, Nos. 1 and 2, belong to a species closely allied to sartorite and smithite. Many new forms for sartorite were found.'

was thought possible that bi-angular measurements of the latter crystals on the three-circle goniometer might suggest a clue to the riddle, and accordingly an appeal was made to Trechmann for the loan of his crystals. With characteristically ready courtesy, which we are glad to have the opportunity of acknowledging, he at once sent all the crystals referred to in his memoir, together with two others which he had acquired since

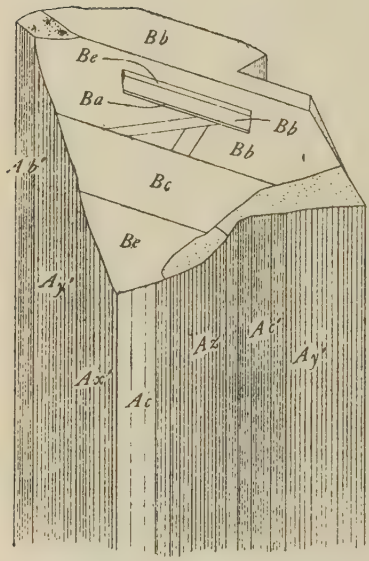

Fig. 1.—Sartorite crystal ; habit No. 1 (B.M. 1918, 408 (2)). See p. 314.

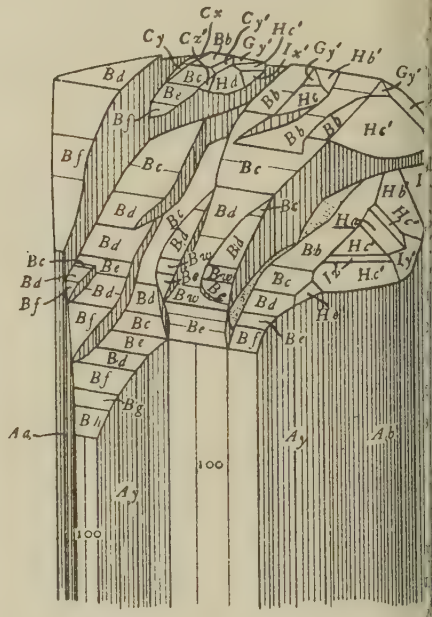

Fig. 2.—Sartorite crystal ; irregular gro (B.M. 1918, 408 (59)).

its publication. All of them were measured, but it was his crystal that was found to be of the first importance; upwards of a hundre faces were observed on the end of the crystal, and a study of the position of the corresponding poles, when plotted on a gnomonic projection, re vealed certain curious zonal relations. With the light thus thrown o the problem by this one crystal the whole of the crystals belonging t both Solly and Trechmann were measured and studied. The conclusion arrived at are discussed below (p. 305).

II. Morphological Characters.

Crystals of sartorite may be classified according to three different kinds of habit:—

(1) Dome-zone (100 : 010) large with bright, smooth planes, and prism-zone (100 : 001) well developed, though deeply grooved (cf. fig. 1). A few crystals show pyramids (cf. figs. 4–9).

(2) Dome-zone (100 : 010) large, but irregularly developed owing to interruptions in the growth of the faces. The crystals sometimes have a tessellated appearance due to repeated twinning, and are sometimes cavernous, the interior of the holes being lined with faces in harmony with the external development (cf. figs. 2 and 3).

(3) Columnar crystals, deeply striated, which have been attached at both ends to the dolomite, and are therefore without faces at the ends. They have been found in masses weighing as much as a hundred grams.

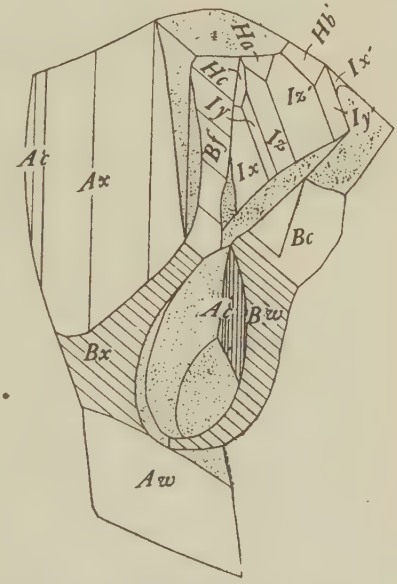

Fig. 3.—Sartorite crystal; cavernous growth (B.M. 1918, 408 (54)).

Twinning about (100) appears to be invariable, and it is often repeated so that the crystals are laminated; even in the case of crystals without faces at the ends the re-entrant angles in the prism-zone testify to the presence of twinning. Crystals are occasionally grouped together in parallel or nearly parallel position, and sometimes cross; it is doubtful, however, whether the latter phenomenon is due to twinning (cf. p. 268).

There is a fair cleavage parallel to (100), and the fracture is of the ordinary conchoidal type. The crystals are extremely brittle, and occasionally break with an audible report, as was noticed by vom Rath. The hardness is about the same as calcite, viz. 3. The colour is lead-grey, the lustre metallic, and the streak chocolate-brown in colour. The crystals are, of course, opaque. The general symmetry is monoclinic,

the plane of symmetry being at right angles to the length of the crystals; but, as is explained below, the crystal development is abnormal in character.

III. Observations on Crystals with Pyramidal Faces.

All the crystals discussed below were measured on the smaller three-circle goniometer in the British Museum, viz. the one which was devised by Herbert Smith in 1899,[1] in every instance the striated prism-zone being selected as the zone of reference. All of them were measured from the cleavage-face (100), as origin, and, where the development of the pyramidal faces was sufficient for the determination of the corresponding poles, from (001), (101), and ($10\bar{1}$) also. The pole (100) could generally be accurately fixed because the corresponding face in nearly every instance yielded a well-defined image and, failing it, the faces in the dome-zone gave usually such excellent reflections that the pole could be fixed with very fair accuracy as the intersection of this zone with the prism-zone. The case was, however, far otherwise with the other poles. Seldom was a definite image available in the extended band of reflections to serve as the origin of measurements, and it was necessary to fix them as the intersection of cross-zones with the prism-zones; but, for reasons which will appear below (cf. p. 305), the large smooth dome-faces were in general not available for this purpose and recourse had to be made to the far smaller pyramidal faces. The settings for the three poles (001), (101), ($10\bar{1}$) could not therefore be determined with very great accuracy; but the amounts of the combined error could be gauged by the closeness with which the angles that they subtended with the pole (100) obeyed the usual anharmonic relation.

Many of the pyramidal faces were extremely small; indeed, it was rare for one to measure more than a tenth of a millimetre across in any direction, and they were often of such minute size that the interatomic repulsive forces which manifest themselves in liquids as surface-tension become relatively pronounced and the faces are perceptibly rounded. In such cases it is therefore far from easy to centre the image on the cross-wires in the telescope of the goniometer, since it is necessarily faint on account of the smallness of the reflecting surface, and is rendered diffuse and indistinct on account of the rounding of the face.

[1] G. F. Herbert Smith, Mineralogical Magazine, 1899, vol. xii, pp. 175–182. It may be mentioned that in October 1906, when a convenient opportunity offered itself, the second circle was returned to Messrs. Troughton and Simms, and the vernier made adjustable, with the view of obviating the small zero correction previously necessary in the case of the azimuthal angles.

As source of illumination a 100 watt half-watt electric lamp, yielding about 200 candle-power, was used, the light being passed through a small beaker of water in order to reduce the amount of heat transmitted and at the same time to diffuse the light from the glowing wire over the object-slit of the goniometer; in order to secure greater uniformity of illumination a thin piece of oiled paper was placed just in front of the object-slit. By screening the crystal-holder and wax, and, in fact, all but the crystal, from the light a perfectly dark background was secured in the field of the telescope of the goniometer, against which even an extremely faint and nebulous image could successfully be picked up after the approximate position had been first found by means of the microscope into which the telescope may be converted.

We will now proceed to describe the six crystals which alone boast a sufficient development of the pyramidal faces for the determination of their zonal characters, and to give in full detail the bi-angular measurements made on each face. Strictly speaking, the number of distinct crystals is five, because the first two of them are really opposite ends of one and the same crystal. With this exception none of the crystals was doubly terminated.

It will, however, first be necessary to say a few words in explanation of the tables of co-ordinates. For reasons which are discussed below (p. 305) we have come to the conclusion that the faces appearing on the ends of the crystals can be referred to three distinct and incongruent space-lattices; these are numbered I, II, III respectively in the tables. The first of them has monoclinic symmetry, and, including, as it does, the dome-zone, is the most prominent of them. The other two have triclinic symmetry, but each of them is twinned about the pole (010), so that in such a crystal as No. 1 there are no fewer than five distinct lattices traceable in the crystal. Lattice II is far better developed than lattice III; but it is to the latter that the solitary pyramidal form observed by vom Rath and selected by him as the unit pyramid belongs. The prism-zone is common to all three lattices. As data for computing the elements of the several lattices and the co-ordinates of the faces corresponding to them we selected the angle $(100):(110)$,[1] either as directly measured or as calculated from a more trustworthy angle in the same zone, and the most concordant set of angles subtended by the poles (001), (101), and $(10\bar{1})$ at (100) as determined by the cross-zonal relations of the pyramidal faces. In the case of the triclinic lattices we have still to select the pole to bear the indices (010). It should be near the

[1] This is the face (041) of vom Rath and Baumhauer.

corresponding pole of lattice I, but which one is determined by the consideration that on the gnomonic projection a slight lateral shift away from the centre should bring the poles of one lattice into coincidence with those of the adjacent one. The azimuthal angles, ϕ_2, ϕ_3, of the zones belonging to the lattices II and III are very simply derived from the corresponding azimuthal angle ϕ_1 of I by the relations $\cot\phi_2 - \cot\phi_1 = c$, and $\cot\phi_3 - \cot\phi_1 = 2c$, where c is a constant for the particular pole of the crystal, but varies for this pole from crystal to crystal (cf. below p. 310).

For designating the forms we have found it convenient to make use of a two-letter notation, the principle of which—viz. the determination of a pole as the intersection of two zones—will be evident from a study of the gnomonic projection shown in fig. 10 (p. 306). Capital letters denote zones passing through (100), and small letters cross-zones passing through (001); but, whereas all poles with the same capital letter lie in the same zone, that is true in the case of poles with the same small letter in general only when they belong to the same space-lattice. Poles lying within dissimilar quadrants are distinguished by a dash; thus *Hb* is (112), *Hb′* ($\bar{1}12$) or ($11\bar{2}$). The prism-zone has been harmonized with the dome-zone, but, of course, the significance of the small letters is no longer the same; thus *Aa* is (001), *Ba* (010), *Ab* (101), *Bb* (110), *Ab′* ($\bar{1}01$), *Bb′* ($\bar{1}10$), and so on.

Crystal No. 1 (*fig.* 4).

This remarkable crystal (Trechmann's No. 5; B.M. 1917, 392), which, before removal from the dolomite matrix, formed part of a slightly larger individual, measures about 1·2 mm. in length, and 0·9 by 0·5 mm. in cross-section. The illustration is a reproduction of an orthogonal drawing projected on to a plane perpendicular to the edge of the prism-zone. The drawing was prepared with the aid of a microscope fitted with a camera lucida, and gives as faithful a picture of the end of the crystal as was found to be practicable. Work of this kind presents considerable difficulty, because, owing to the extremely small size of the crystal; an objective of high power had to be used, and consequently any edge, or even any part of an edge, lying appreciably outside the focal plane was indistinct, if not partly or wholly indiscernible, and the necessary adjustment of the focus invariably upset the coincidence between the drawing and the visual picture. With care it was possible to some extent to overcome this difficulty, but, to assure accuracy, the

relative inclinations of the edges on the drawing were determined in the customary manner from a gnomonic projection.

The crystal is twinned about (100), the sector running sideways across the middle being in twinned position with respect to those above and below it, which themselves are therefore in parallel position. The boundaries are very straight and sharp, slight interpenetration taking place only in the case of the lower one on the left-hand side. The large stippled portions represent fractured portions, and the narrow stippled patches, running up and down, indicate clefts, which are lined with faces in harmony with the external development; the narrowness of the

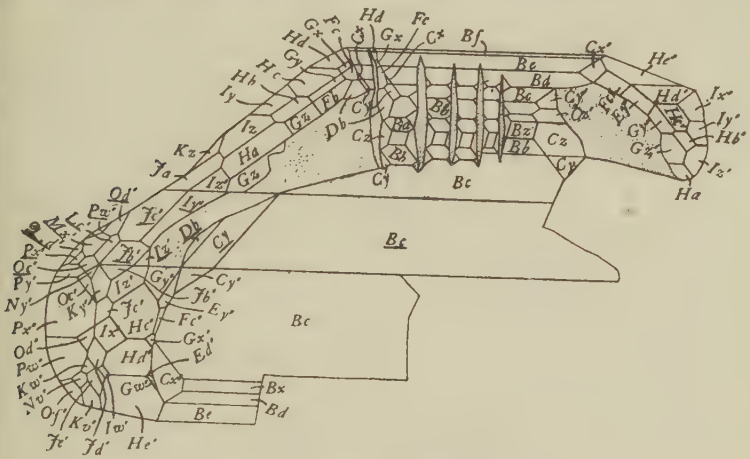

FIG. 4. Sartorite crystal No. 1.

clefts in comparison with their depth prevented observations being made of the faces lying at the bottom. The corresponding faces on the several humps are very nearly parallel to one another, the spreading of the combined reflection being only slight. At the right-hand top-corner of the crystal in the position of the figure occur a number of additional faces, of which some were in the twinned position; they were omitted from the drawing, because otherwise, owing to the lack of perspective, their presence would have led to confusion. Reflections corresponding to isolated crystal-faces occur also on the fractured part of the crystal on the right-hand side as seen in the drawing. An extremely small crystal of pyrites emerges from the prism-zone low down towards the right-hand corner in the position depicted.

Altogether, on the end of the crystal observations were made of no

fewer than 123 different faces, representing sixty-seven different forms, and it may be remarked that in arriving at this number we reckoned parallel faces as one. Of these faces fifteen lie in the dome-zone, and therefore 108 are pyramidal. Eighty-five of the faces appear in the figure; the remainder are mostly too minute to be drawn even on that large scale, only a few of them being peculiar to the part of the crystal omitted from the drawing. The left-hand bottom-corner of the crystal is by far the best developed portion of it. As we pass to the upper corner on the same side, we find the faces rapidly diminishing in size, and the growth becoming interrupted and irregular, more so than, owing to the minuteness of the faces, could be indicated on the drawing. The reflections from the large faces in the dome-zone were brilliant and sharp, but from the faces on the farther side they were dispersed and extended in the direction of the zone owing to the rounding that always accompanies narrowness of width in faces. The twin-individuals shown in the figure are combined in such a way that only close observation at a glancing angle will reveal on the large face *Bb* the fine lines indicative of the twin boundaries. Since at the re-entrant angle on the left-hand side of the crystal the prism-zone on both individuals is considerably striated, an overlapping pair of banded reflections was afforded in the field of the telescope of the goniometer, and to determine to which of the two individuals a particular image belonged was a task of some difficulty. The near face (100) was small and considerably stepped, but gave a single distinct reflection; the farther one, on the other hand, was large and divided vertically into two parts which gave readings differing by 21′.

That there is something unusual in the zonal characters of the crystal is suggested by the perceptibly wedge-shaped contour of such faces as *Jc′*, *Fc′*, and *Ey′*, certain opposing edges being nearly, but unmistakably not, parallel to one another as we should expect to find in the case of an ordinary crystal.

There are two faces, viz. *Gw′* and *Gx′*, which are not quite in the position where we should have expected to find them, the azimuthal angle subtended at (100) as origin differing, as will be seen from table below, by about a degree of arc from that of *Gy′*, which is normal in position and which should presumably have been in their zone. Possibly the cause may be their relative smallness of size as compared with the contiguous faces belonging to another lattice.

The elements of the crystal and the co-ordinate angles of the various forms were computed from the following angles:—(100) : (001) = 74° 28′ (the observed value), 100 : 101 = 36° 6′ (observed value 36° 4′),

$(100):(10\bar{1}) = 50°\ 48'$ (observed value 50° 40′), and $(100):(210) = 51°\ 7'$ (the observed value).[1] In the prism-zone, owing to its oscillatory character, it was often difficult, if not impossible, to assert with confidence whether a particular reflection corresponded to a positive or a negative face; accordingly, in many instances both sets of indices corresponding to a particular angle were computed, and the simpler of them, if the corresponding angle was in fair agreement, was selected. The question of the development of this zone is discussed more fully below (p. 314).

The shear governing the transition from lattices I to II and II to III was determined thus:—If ϕ_1, ϕ_2, ϕ_3 be the azimuthal angles, measured from the prism-zone, of some particular pole (*hkl*) in the various lattices subtended at any pole in that zone, then the following relations hold

$$\cot \phi_3 - \cot \phi_2 = \cot \phi_2 - \cot \phi_1 = f.A,$$

where A is the cotangent of the azimuth corresponding to the pole (111) in lattice I and f is a fraction. The values of f and A in the case of the four poles (100), (001), (101), (10$\bar{1}$) are—

	f	A
(100) ...	0·3 ...	0·36872
(001) ...	0·1 ...	0·38845
(101) ...	0·1 ...	0·47510
(10$\bar{1}$) ...	0·2 ...	0·62488

Elements of the Lattices.

I. $a:b:c = 2{\cdot}5737:1:2{\cdot}7118$; $\beta = 105°\ 22'$.

II. $a:b:c = 2{\cdot}5769:1:2{\cdot}7309$;
$(010):(001) = 82°\ 51'$, $(001):(100) = 74°\ 28'$, $(100):(010) = 85°\ 57'$;
$\alpha = 96°\ 19'$, $\beta = 105°\ 10'$, $\gamma = 92°\ 13\frac{1}{2}'$.

III. $a:b:c = 2{\cdot}5820:1:2{\cdot}7786$;
$(010):(001) = 75°\ 56'$, $(001):(100) = 74°\ 28'$, $(100):(010) = 82°\ 6'$;
$\alpha = 102°\ 28\frac{1}{2}'$, $\beta = 104°\ 7'$, $\gamma = 94°\ 26\frac{1}{2}'$.

[1] The angles stated to have been observed in the prism-zone were those determined from the cross-zonal relations of the pyramidal faces by means of the third circle of the three-circle goniometer. Wherever possible, three angles were thus measured, of which theoretically only two were necessary; the actual angles taken as data were, however, those considered, having regard to the probable accuracy of the adjustment of the several origins, to accord best with the measured angles. In the case of crystals 3 and 5, a somewhat similar procedure was adopted for the dome-zone, the datum angle being based on more than one angle.

Table IV. Calculated and observed values of the co-ordinate angles.

Face.			Refl.[1]	Observed.		Calculated.	
Lattice.	Symbols.	Indices.		ϕ	ρ	ϕ	ρ
(a) Co-ordinates from (100)—							
	Ad'	$30\bar{1}$	g	0° 0′	18° 35′	0° 0′	18° 25½′
		$60\bar{5}$	b	,, ,,	44 4	,, ,,	44 2
	Ab'	$10\bar{1}$	b	,, ,,	50 8	,, ,,	50 48
		$50\bar{9}$	s	,, ,,	71 37	,, ,,	71 45
		$30\bar{7}$	s	,, ,,	79 37	,, ,,	79 12
	Ad	301	b	,, ,,	15 33	,, ,,	15 42
		$50\bar{3}$	b	,, ,,	32 31	,, ,,	32 55
	Az	102	s	,, ,,	49 48	,, ,,	50 29½
		207	s	,, ,,	59 10	,, ,,	59 22
	Aa	001	f	,, ,,	73 50	,, ,,	74 28
		409	b	,, ,,	78 1	,, ,,	78 15
		$3.0.\bar{1}0$	f	,, ,,	87 32	,, ,,	87 8
	Af	$50\bar{1}$	s	,, ,,	11 39	,, ,,	10 54½
	Ad	301	f	,, ,,	15 35	,, ,,	15 42
		$40\bar{3}$	b	,, ,,	42 25	,, ,,	42 20
	Ab'	$10\bar{1}$	f	,, ,,	50 48	,, ,,	50 48
		104	f	,, ,,	61 52	,, ,,	61 8
		108	b	,, ,,	67 14	,, ,,	67 29
	Az'	$10\bar{2}$	b	,, ,,	75 25	,, ,,	74 57
		$10\bar{4}$	b	,, ,,	85 10	,, ,,	86 27
	Aw'	$70\bar{2}$	f	,, ,,	15 47	,, ,,	15 44
		705	f	,, ,,	29 13	,, ,,	28 56
		405	s	,, ,,	42 41	,, ,,	42 34
		305	s	,, ,,	46 33	,, ,,	46 57½
	Az	102	f	,, ,,	50 23	,, ,,	50 29½
		104	b	,, ,,	61 33	,, ,,	61 8
		105	b	,, ,,	63 38	,, ,,	63 25½
	Aa	001	f	,, ,,	74 25	,, ,,	74 28
		$20\bar{5}$	f	,, ,,	80 47	,, ,,	80 56
		$10\bar{4}$	b	,, ,,	86 58	,, ,,	86 27
III		$21\bar{7}$	b	19 0	87 30	18 31	88 14
,,	*Qd'*	$31\bar{5}$	b	25 50	76 39	25 50½	76 24
,,	,,	,,	b	26 1	76 19	,, ,,	,, ,,
,,	*Pw'*	$72\bar{9}$	f	28 0	69 26	28 0	69 14
,,	*Px'*	$52\bar{9}$	f	,, ,,	79 27	,, ,,	79 14½
,,	*Py'*	$32\bar{9}$	f	,, ,,	89 52	,, ,,	89 57½
,,	*Pw'*	$72\bar{9}$	b	28 5	69 23	,, ,,	69 14
,,	*Px'*	$52\bar{9}$	b	,, ,,	79 7	,, ,,	79 14½
II	*Mx'*	$52\bar{9}$	b	29 36	76 47	29 28	76 49½
III	*Of'*	$51\bar{4}$	f	30 33	53 33	30 31	53 22½
,,	*Od'*	$31\bar{4}$	b	,, ,,	71 45	,, ,,	71 32
,,	*Oc'*	$21\bar{4}$	f	,, ,,	82 52	,, ,,	82 38
,,	*Od'*	$31\bar{4}$	b	30 34	71 59	,, ,,	71 32

[1] In the column headed 'Reflections' the letters indicate the quality of the reflected image and therefore the trustworthiness of the measured angle, viz. g good, f fair, b bad, s striated.

III	*Oc'*	21$\bar{4}$	b	30° 34′	83° 38′	30° 31′	82° 38′
II	*Lc'*	21$\bar{4}$	b	32 34	80 1	32 15	80 9
,,	*Lx'*	52$\bar{8}$	b	32 35	74 17	,, ,,	74 17
,,	*Lc'*	21$\bar{4}$	b	,, ,,	80 15	,, ,,	80 9
III	*Nv'*	92$\bar{7}$	b	33 16	54 34	33 29	54 4
,,	,,	,,	f	33 25	54 10	,, ,,	,, ,,
,,	*Ny'*	32$\bar{7}$	b	,, ,,	86 45	,, ,,	86 43
II	*Kv'*	92$\bar{7}$	f	35 36	51 22	35 31	51 11
,,	*Kw'*	72$\bar{7}$	b	,, ,,	60 24	,, ,,	60 18½
,,	*Ky'*	32$\bar{7}$	f	,, ,,	84 14	,, ,,	84 11½
,,	*Kw'*	72$\bar{7}$	b	35 42	60 19	,, ,,	60 18½
,,	*Kz*	12$\bar{7}$	b	35 44	69 41	,, ,,	69 51½
,,	*Je'*	41$\bar{3}$	b	39 19	52 20	39 25	51 55
,,	*Jd'*	31$\bar{3}$	b	,, ,,	62 28	,, ,,	62 11
,,	*Jc'*	21$\bar{3}$	b	,, ,,	74 33	,, ,,	74 48
,,	*Jb'*	11$\bar{3}$	b	,, ,,	89 15	,, ,,	89 6
,,	*Je'*	41$\bar{3}$	f	39 30	51 59	,, ,,	51 55
,,	*Jd'*	31$\bar{3}$	f	,, ,,	62 18	,, ,,	62 11
,,	*Jc'*	21$\bar{3}$	f	,, ,,	74 53	,, ,,	74 48
,,	*Jb'*	11$\bar{3}$	f	,, ,,	89 4	,, ,,	89 6
,,	,,	,,	f	,, ,,	89 11	,, ,,	,, ,,
,,	*Ja*	01$\bar{3}$	f	39 35	76 26	,, ,,	76 23
,,	*Jc'*	21$\bar{3}$	f	,, ,,	74 52	,, ,,	74 48
,,	*Iv'*	92$\bar{5}$	b	44 2	44 44	44 5	44 1½
,,	*Iw'*	72$\bar{5}$	b	,, ,,	53 14	,, ,,	52 59
,,	*Ix'*	52$\bar{5}$	f	,, ,,	64 43	,, ,,	64 38½
,,	*Iy'*	32$\bar{5}$	f	,, ,,	79 3	,, ,,	79 4
,,	*Iz'*	12$\bar{5}$	f	,, ,,	85 9	,, ,,	85 0
,,	,,	,,	f	44 6	84 51	,, ,,	85 0
,,	*Iw'*	72$\bar{5}$	b	,, ,,	53 4	,, ,,	52 59
,,	*Ix'*	52$\bar{5}$	f	,, ,,	64 43	,, ,,	64 39½
,,	*Iy'*	32$\bar{5}$	f	,, ,,	79 7	,, ,,	79 4
,,	*Iz'*	12$\bar{5}$	b	,, ,,	85 9	,, ,,	85 0
,,	,,	,,	f	,, ,,	84 56	,, ,,	,, ,,
,,	*Iy'*	32$\bar{5}$	b	44 13	79 11	,, ,,	79 4
,,	*Iz*	125	f	,, ,,	69 47	,, ,,	69 48
,,	*Iy*	325	f	,, ,,	57 6	,, ,,	57 2½
,,	*Ic*	7·4·10	b	,, ,,	50 31	,, ,,	51 44½
,,	*He'*	41$\bar{2}$	b	49 28	44 42	49 42	44 27
,,	*Hd'*	31$\bar{2}$	f	,, ,,	54 51	,, ,,	54 33
,,	*Hc'*	21$\bar{2}$	b	,, ,,	68 15	,, ,,	67 58½
,,	*Ha*	012	b	,, ,,	77 20	,, ,,	78 7
,,	*Hb'*	11$\bar{2}$	b	,, ,,	84 49	,, ,,	84 28
,,	*He'*	41$\bar{2}$	f	49 37	44 32	,, ,,	44 27
,,	*Hd'*	31$\bar{2}$	f	,, ,,	54 36	,, ,,	54 33
,,	*Hc'*	21$\bar{2}$	f	,, ,,	68 2	,, ,,	67 58½
,,	*Hd*	312	b	49 40	41 36	,, ,,	41 26
,,	*Hc*	212	b	,, ,,	50 43	,, ,,	50 28
,,	*Hb*	112	b	,, ,,	62 13	,, ,,	62 37
,,	*Ha*	012	f	,, ,,	78 1	,, ,,	78 7
,,	*He'*	41$\bar{2}$	f	49 57	44 18	,, ,,	44 27
,,	*Hc*	212	b	,, ,,	50 30	,, ,,	50 28
,,	*Hd'*	31$\bar{2}$	b	,, ,,	54 28	,, ,,	54 33
,,	*Hb*	112	b	,, ,,	62 21	,, ,,	62 37
,,	*Hc'*	21$\bar{2}$	b	,, ,,	67 30	,, ,,	67 58½
,,	,,	,,	b	,, ,,	68 28	,, ,,	,, ,,
,,	*Ha*	012	f	,, ,,	77 55	,, ,,	78 7
,,	*Gw'*	72$\bar{3}$	b	55 20	45 30	56 26	45 20
,,	*Gx'*	52$\bar{3}$	b	,, ,,	57 10	,, ,,	56 52

II	*Gy′*	323	f	56° 13′		72° 19′		56° 26′		72° 26′	
,,	*Gx*	523	b	,,	,,	44 15		,,	,,	44 12½	
,,	*Gy*	323	f	,,	,,	55 5		,,	,,	55 21	
,,	*Gz*	123	b	,,	,,	70 9		,,	,,	70 26½	
,,	*Gz′*	1̄23	b	,,	,,	88 30		,,	,,	88 54	
,,	*Gy′*	323	b	56	14	72 42		,,	,,	72 26	
,,	*Gx*	523	b	56	32	44 5		,,	,,	44 12½	
,,	*Gz*	123	b	,,	,,	70 3		,,	,,	70 26½	
,,	*Gy′*	323	b	,,	,,	73 43		,,	,,	72 26	
I	*Ed′*	623	b	60	33	46 51		61 3		47 16	
,,	*Ey′*	323	b	,,	,,	69 3		,,	,,	68 27½	
,,	,,	,,	b	61	2	68 32		,,	,,	,,	,,
II	*Fc′*	21̄1	b	64	0	59 58		64 24		60 17	
,,	,,	,,	b	64	2	60 34		,,	,,	,,	,,
,,	*Fc*	211	b	64	11	49 11		,,	,,	48 32	
,,	*Fb*	111	b	,,	,,	62 13		,,	,,	62 31	
I	*Dd*	311	b	68	50	38 52		69 45½		39 5	
,,	*Db*	111	b	69	41	65 12		,,	,,	64 37	
,,	*Dd*	311	b	70	3	38 20		,,	,,	39 5	
,,	*Db*	111	f	,,	,,	64 33		,,	,,	64 37	
,,	*Cz*	121	b	78	28	76 6		79 33		76 2	
,,	*Cx*	521	b	79	28	43 41		,,	,,	43 50	
,,	*Cy*	321	b	,,	,,	57 14		,,	,,	57 10	
,,	*Cz*	121	b	,,	,,	75 59		,,	,,	76 2	
,,	*Cx′*	52̄1	f	79	31	46 52		,,	,,	46 45½	
,,	*Cy′*	32̄1	b	,,	,,	62 3		,,	,,	61 25½	
,,	*Cx′*	52̄1	f	79	37	46 42		,,	,,	46 45½	
,,	*Cy*	321	f	,,	,,	57 8		,,	,,	57 10	
,,	*Cy′*	32̄1	b	,,	,,	61 24		,,	,,	61 25½	
,,	*Cz′*	12̄1	b	,,	,,	81 30		,,	,,	81 35	
,,	*Ca*	021	b	79	50	86 35		,,	,,	87 7	
,,	*Cx*	521	f	79	59	43 44		,,	,,	43 50	
,,	*Cz*	121	b	,,	,,	76 3		,,	,,	76 2	
,,	*Cx′*	52̄1	b	,,	,,	46 35		,,	,,	46 45½	
,,	,,	11·1·0	b	89	25	12 54		90 0		12 42	
,,	*Bh*	710	b	,,	,,	19 35		,,	,,	19 31	
,,	*Bf*	510	b	,,	,,	26 39		,,	,,	26 23	
,,	*Bd*	310	b	,,	,,	39 34		,,	,,	39 35	
,,	*Bx*	520	s	,,	,,	45 0		,,	,,	44 46	
,,	*Bc*	210	g	,,	,,	51 8		,,	,,	51 7	
,,	*Bb*	110	b	,,	,,	68 1		,,	,,	68 2½	
,,	*Bz*	120	b	,,	,,	78 24		,,	,,	78 36	
,,	*Ba*	010	b	,,	,,	89 41		,,	,,	90 0	
,,	*Bf*	510	b	89	55	26 11		,,	,,	26 23	
,,	*Be*	410	b	,,	,,	31 50		,,	,,	31 48	
,,	*Bd*	310	b	,,	,,	39 25		,,	,,	39 35	
,,	*Bc*	210	b	,,	,,	50 26		,,	,,	51 7	
,,	*By*	320	b	,,	,,	45 0		,,	,,	44 42½	
,,	*Bb*	110	b	,,	,,	68 33		,,	,,	68 2½	
(b) Co-ordinates from (001)—											
III	*Of′*	51̄4	b	28	57	59 33		28 12		59 35	
,,	*Nv′*	927	b	30	43	60 21		30 54		60 26	
II	*Kv′*	92̄7	b	,,	,,	63 48		30 20		63 41	
,,	*He′*	41̄2	f	33	34	75 33		33 26		75 48½	
,,	*Je′*	41̄3	b	33	58	65 6		,,	,,	65 7	
,,	*He′*	41̄2	f	,,	,,	75 42		,,	,,	75 48½	
,,	*Jd′*	31̄3	b	41	34	57 38		41 36		57 46	
,,	*Hd′*	31̄2	f	,,	,,	69 14		,,	,,	69 22	

III	Od'	$31\bar{4}$	b	42° 40′	45° 14′	42° 36′	45° 22½′
I	Cx	$52\bar{1}$	b	45 15	79 6	45 50	79 2½
,,	Cx'	$52\bar{1}$	f	45 50	86 52	47 0½	86 46
,,	,,	,,	b	46 11	86 52	,, ,,	,, ,,
II	Gx'	$52\bar{3}$	b	46 33	71 33	,, ,,	72 33
,,	Ix'	$52\bar{5}$	f	47 0	59 10	,, ,,	59 17
,,	,,	,,	b	47 24	58 58	,, ,,	,, ,,
III	Px'	$52\bar{9}$	f	48 9	38 3	48 13	38 13
I	Bc	$21\bar{0}$	g	52 7	80 16	52 9	80 19½
II	Jc'	$21\bar{3}$	b	53 30	49 30	53 34	49 36
,,	Hc'	$21\bar{2}$	f	,, ,,	61 18	,, ,,	61 29½
,,	Jc'	$21\bar{3}$	b	53 45	49 30	,, ,,	49 36
,,	Hc'	$21\bar{2}$	b	,, ,,	61 15	,, ,,	61 29½
,,	Fc'	$21\bar{1}$	b	,, ,,	76 19	,, ,,	76 46
III	Oc'	$21\bar{4}$	b	54 51	37 40	55 2	37 55½
I	Ey'	$32\bar{3}$	b	59 51	70 19	59 46	70 24
,,	,,	,,	b	60 10	69 31	,, ,,	,, ,,
,,	Cy'	$32\bar{1}$	b	60 33	88 6	,, ,,	88 33
II	Ky'	$32\bar{7}$	b	61 18	41 5	61 28	41 8
,,	Iy'	$32\bar{5}$	f	,, ,,	50 56	,, ,,	51 2½
,,	Gy'	$32\bar{3}$	b	,, ,,	64 31	,, ,,	64 43
,,	Iy'	$32\bar{5}$	f	61 46	50 50	,, ,,	51 2½
,,	Gy'	$32\bar{3}$	b	,, ,,	64 16	,, ,,	64 43
III	Py'	$32\bar{9}$	b	63 13	31 33	63 12	31 44
II	Hb	$11\bar{2}$	b	66 30	47 21	66 52	47 25½
,,	Fb	$11\bar{1}$	b	,, ,,	60 1	,, ,,	60 27½
I	Db	$11\bar{1}$	b	68 51	65 23	68 46	65 25
,,	Bb	$11\bar{0}$	b	,, ,,	84 14	,, ,,	84 15
II	Jb'	$11\bar{3}$	b	70 28	42 13	70 43	42 16
,,	Kz	$12\bar{7}$	b	76 46	33 58	76 53	34 3½
,,	Iz	$12\bar{5}$	f	,, ,,	41 59	,, ,,	42 6
,,	Gz	$12\bar{3}$	b	,, ,,	53 17	,, ,,	53 43
I	Cz'	$12\bar{1}$	b	78 44	84 5	79 0½	82 19
,,	Bz	$12\bar{0}$	b	,, ,,	87 5	,, ,,	86 58
II	Iz'	$12\bar{5}$	f	81 6	44 20	81 10	44 32½
,,	Gz'	$12\bar{3}$	b	,, ,,	56 43	,, ,,	57 28
,,	Iz'	$12\bar{5}$	f	81 34	44 23	,, ,,	44 32½
,,	Gz'	$12\bar{3}$	b	,, ,,	56 44	,, ,,	57 28
,,	Ha	$01\bar{2}$	b	87 23	48 2	87 46½	48 19
,,	Ja	$01\bar{3}$	f	87 51	38 0	,, ,,	38 9½
,,	Ha	$01\bar{2}$	f	,, ,,	48 6	,, ,,	48 19
(c) Co-ordinates from (101)—								
III	Of'	$51\bar{4}$	b	24 18	85 34	24 7½	85 42½
,,	Nv'	$92\bar{7}$	b	26 12	85 34	26 37	85 37½
,,	Oe'	$41\bar{4}$	b	26 46	85 44	,, ,,	86 21
,,	Pw'	$72\bar{9}$	f	,, ,,	78 20	,, ,,	78 28½
,,	Qd'	$31\bar{5}$	b	,, ,,	70 48	,, ,,	71 1
II	Kv'	$92\bar{7}$	b	27 20	82 17	27 10½	82 22
III	Px'	$52\bar{9}$	g	29 48	68 48	29 38	68 53
,,	Od'	$31\bar{4}$	b	,, ,,	76 52	,, ,,	76 58
II	Je'	$41\bar{3}$	f	30 25	81 48	30 19	81 56
,,	Kw'	$72\bar{7}$	b	,, ,,	89 12	,, ,,	89 4
III	Py'	$32\bar{9}$	f	33 25	58 31	33 20	58 42
,,	Oc'	$21\bar{4}$	f	,, ,,	66 17	,, ,,	66 26
,,	He'	$41\bar{2}$	b	34 16	72 11	34 10½	71 56
,,	Iw'	$72\bar{5}$	b	,, ,,	81 40	,, ,,	81 27
,,	Id'	$31\bar{3}$	b	,, ,,	88 21	,, ,,	88 33
,,	,,	,,	f	34 20	88 29	,, ,,	,, ,,

III	*Gw′*	623	b	39° 4′	70° 54′	38° 59½′	70° 20½′
,,	*Hd′*	312	f	,, ,,	80 55	,, ,,	80 53½
,,	*Ix′*	525	f	,, ,,	87 54	,, ,,	87 54½
,,	*Ky′*	327	f	,, ,,	66 45	,, ,,	66 43
,,	*Jc′*	213	f	,, ,,	76 50	,, ,,	76 52
,,	*Hd′*	312	b	39 10	81 13	,, ,,	80 53½
,,	*Ix′*	525	b	,, ,,	87 40	,, ,,	87 54½
,,	*Jc′*	213	b	,, ,,	77 0	,, ,,	76 52
,,	*Jb′*	113	f	45 8	63 44	45 4	63 45
,,	*Iy′*	325	f	,, ,,	74 44	,, ,,	74 48
,,	*Hc′*	212	g	,, ,,	87 1	,, ,,	87 7½
,,	,,	,,	b	,, ,,	86 56	,, ,,	,, ,,
,,	*Jb′*	113	b	,, ,,	63 45	,, ,,	63 45
,,	*Iy′*	325	b	,, ,,	74 40	,, ,,	74 48
,,	*Iz′*	125	f	52 48	60 30	52 45½	60 32
,,	*Hb′*	112	b	,, ,,	72 17	,, ,,	72 28½
,,	*Fc′*	211	b	,, ,,	80 1	,, ,,	79 40
,,	*Gy′*	323	b	,, ,,	85 55	,, ,,	86 11
I	*Bd*	310	b	54 27	51 31	54 31½	51 29
,,	*Cx′*	521	f	,, ,,	61 30	,, ,,	61 35
,,	,,	,,	b	54 40	61 39	,, ,,	,, ,,
,,	*Ey′*	323	b	,, ,,	88 10	,, ,,	88 12
II	*Ha*	012	b	62 20	57 16	62 24½	57 22
,,	*Iz*	125	f	62 26	47 27	,, ,,	47 27
,,	*Ha*	012	f	,, ,,	57 19	,, ,,	57 22
,,	*Gz′*	123	b	,, ,,	69 19	,, ,,	70 3
I	*Cx*	521	b	64 33	48 52	64 35	48 56½
,,	*Bc*	210	b	,, ,,	59 19	,, ,,	59 31½
,,	*Cy′*	321	b	,, ,,	73 50	,, ,,	72 59½
,,	*Cx*	521	b	64 34	48 45	,, ,,	48 56½
,,	*Bc*	210	g	,, ,,	59 24	,, ,,	59 31½
,,	*Cy′*	321	b	,, ,,	72 56	,, ,,	72 59½
,,	,,	,,	b	65 6	73 47	,, ,,	,, ,,
II	*Iy*	325	f	74 6	37 24	74 5½	37 24
,,	*Hb*	112	f	,, ,,	44 30	,, ,,	44 48
,,	*Gz*	123	f	,, ,,	54 18	,, ,,	54 45½
I	*Bz*	120	b	83 15	80 46	83 13½	80 49
,,	*Hc*	212	b	87 16	36 22	87 17	36 4½
,,	*Gy*	323	b	,, ,,	43 15	,, ,,	43 20
,,	*Fb*	111	b	,, ,,	52 50	,, ,,	53 13
(d) Co-ordinates from (10$\bar{1}$)—							
I	*Bf*	510	b	33 0	55 31	32 37½	55 31
II	*Kz*	127	b	36 12	68 9	36 2	68 0
,,	*Iy*	325	b	,, ,,	82 57	,, ,,	82 56
,,	*Hc*	212	b	,, ,,	89 8	,, ,,	89 6
III	*Py′*	329	b	39 58	46 51	40 6	46 47½
II	*Ja*	013	f	43 22	64 16	43 16	64 15
,,	*Iz*	125	f	,, ,,	72 19	,, ,,	72 17½
,,	*Hb*	112	b	,, ,,	81 28	,, ,,	81 7
,,	*Gy*	323	b	,, ,,	89 25	,, ,,	89 36½
I	*Bd*	310	b	46 49	60 42	46 51	60 51
,,	*Cx*	521	b	,, ,,	68 59	,, ,,	68 59
III	*Qd′*	315	b	48 40	34 33	48 49	34 15½
,,	*Px′*	529	b	,, ,,	37 54	,, ,,	37 48
,,	*Oc′*	214	b	,, ,,	42 4	,, ,,	42 0½
II	*Ky′*	327	f	52 46	46 19	53 8	46 15
,,	*Jb′*	113	b	,, ,,	52 32	,, ,,	52 31
,,	*Iz′*	125	f	,, ,,	60 6	,, ,,	

II	*Ha*	012	f	52° 46′	68° 52′	53° 8′	68° 53′
,,	*Gz*	123	f	,, ,,	78 55	,, ,,	78 55
,,	*Fb*	111	b	,, ,,	89 40	,, ,,	89 41
,,	*Ib′*	113	b	52 47	52 35	,, ,,	52 31
,,	*Iz′*	123	b	,, ,,	60 8	,, ,,	60 2
,,	*Ha*	012	b	,, ,,	68 58	,, ,,	68 53
,,	*Gz*	123	b	,, ,,	79 1	,, ,,	78 55
I	*Bc*	210	b	57 30	66 2	58 0	66 37½
,,	*Cx′*	52$\bar{1}$	f	58 2	57 29	,, ,,	57 37½
,,	*Bc*	210	g	,, ,,	66 36	,, ,,	66 37½
,,	*Db*	111	b	58 4	88 21	,, ,,	88 21½
,,	*Cx′*	52$\bar{1}$	b	58 22	77 23	,, ,,	77 1½
,,	*Cy*	321	b	,, ,,	57 36	,, ,,	57 37½
,,	*Db*	111	b	,, ,,	88 10	,, ,,	88 21½
II	*Pw′*	72$\bar{9}$	f	60 39	30 18	60 39	30 14½
,,	*Od′*	31$\bar{4}$	b	,, ,,	33 40	,, ,,	33 33
II	*He′*	41$\bar{2}$	f	63 48	36 34	63 26	36 40
,,	*Gz′*	123	b	65 36	65 19	66 22½	65 24
,,	*Jc′*	21$\bar{3}$	b	65 41	41 50	,, ,,	41 58
,,	*Iy′*	32$\bar{5}$	b	,, ,,	48 21	,, ,,	48 13
,,	*Hb′*	11$\bar{2}$	b	,, ,,	56 7	,, ,,	55 57
,,	*Gz′*	123	b	,, ,,	64 45	,, ,,	65 24
,,	*Jc′*	21$\bar{3}$	b	66 30	42 8	,, ,,	41 58
,,	*Iy′*	32$\bar{5}$	b	,, ,,	48 15	,, ,,	48 13
I		11$\bar{2}$	b	72 25	56 30	72 39	56 0
,,	*Ez′*	123	b	,, ,,	65 50	,, ,,	65 53½
,,	*Da*	011	?	,, ,,	80 20	,, ,,	78 5
,,	*Cz*	121	b	,, ,,	89 5	,, ,,	89 5
,,	*Cy′*	32$\bar{1}$	b	72 47	64 41	,, ,,	64 48½
,,	*Bb*	110	b	,, ,,	76 8	,, ,,	76 20
,,	*Cz*	121	b	,, ,,	89 5	,, ,,	89 5
III	*Fe′*	21$\bar{1}$	b	79 45	52 29	79 23	52 50
,,	*Kv′*	927	b	79 46	27 45	,, ,,	27 25
,,	*Je′*	41$\bar{3}$	f	,, ,,	30 34	,, ,,	30 34
,,	*Iw′*	72$\bar{5}$	b	,, ,,	34 26	,, ,,	34 25
,,	*Hd′*	31$\bar{2}$	f	,, ,,	39 10	,, ,,	39 12
,,	*Gx′*	523	b	80 15	44 30	,, ,,	45 14
,,	*Je′*	41$\bar{3}$	b	80 30	30 24	,, ,,	30 34
,,	*Iw′*	72$\bar{5}$	b	,, ,,	34 14	,, ,,	34 25
,,	*Hd′*	31$\bar{2}$	b	,, ,,	39 5	,, ,,	39 12
,,	*Fc′*	21$\bar{1}$	b	,, ,,	52 48	,, ,,	52 50
,,	*Kw′*	727	b	82 7	30 33	82 52½	30 34
,,	*Jd′*	31$\bar{3}$	b	,, ,,	34 33	,, ,,	34 28
,,	*Ix′*	52$\bar{5}$	f	,, ,,	39 21	,, ,,	39 19
,,	*Hc′*	21$\bar{2}$	b	,, ,,	45 23	,, ,,	45 26½
,,	*Gy′*	323	b	,, ,,	53 3	,, ,,	53 11
,,	*Kw′*	727	b	82 58	30 30	,, ,,	30 34
,,	*Jd′*	31$\bar{3}$	f	,, ,,	34 35	,, ,,	34 28
,,	*Ix′*	52$\bar{5}$	f	,, ,,	39 20	,, ,,	39 19
,,	*Hc′*	21$\bar{2}$	f	,, ,,	45 21	,, ,,	45 26½
,,	*Gy′*	323	f	,, ,,	52 56	,, ,,	53 11
III	*Of′*	51$\bar{4}$	b	86 33	24 20	86 25½	24 6
,,	*Nv′*	927	b	,, ,,	26 33	,, ,,	26 35
I	*Ey′*	323	b	89 3	54 30	90 0	54 29
,,	,,	,,	b	89 40	54 24	,, ,,	,, ,,
,,	*Cz′*	12$\bar{1}$	b	89 56	76 54	,, ,,	76 37
,,	*Ba*	010	b	,, ,,	89 48	,, ,,	90 0

Crystal No. 2 (*fig.* 5).

This tiny crystal (Trechmann's No. 6; B.M. 1917, 392), which measures about 1 mm. in length and about 0·2 by 0·2 mm. in cross-section, originally formed, as has been explained, with the preceding crystal opposite ends of a single individual. According to Trechmann [1] the central portion of this individual was overlain by a similar one, almost at right angles to it, and he mentions the suggestion made by Baumhauer [2] that such a conjunction, which has several times been observed, resulted from twinning. That may be true, because, as will be seen from the gnonomic projection (fig. 10), twinning about at least

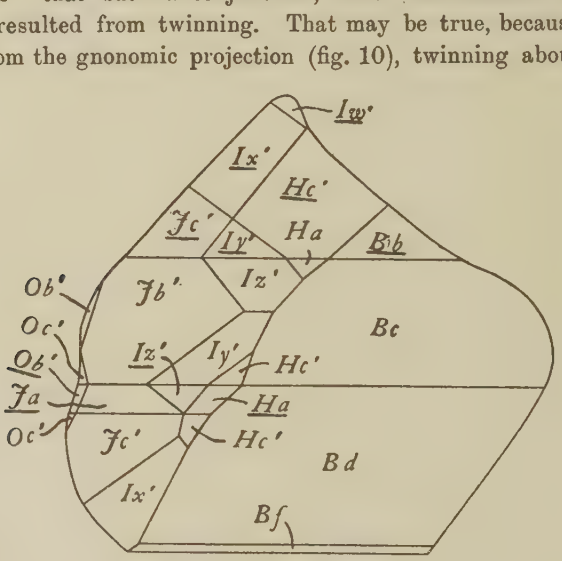

Fig. 5. Sartorite crystal No. 2.

four poles, viz. *Bx*, *Gx'*, *Hc'*, *Iz'*, would result in the prism-zones of th two individuals crossing nearly at right angles. Actual measuremen of such a group will, however, be necessary before the existence c twinning of this kind can be accepted; in the case of Trechmann crystals 3 and 4 the mutual relation is not ordinary twinning (cf. p. 268

Altogether, 19 pyramidal faces, representing 14 forms, and 7 dom faces, representing 7 forms, were observed; as is implied by the latt half of the statement, only one half of the dome-zone is develope Some of the pyramidal faces are striated parallel to the edge of the zo connecting them with (100), the result of repeated twinning about t latter. Except for the faces of the form (100), the prism-zone is muc

[1] Loc. cit., p. 226. [2] Loc. cit., p. 251.

striated, and gives bands of reflections extending over wide angles; in the table below the angles given refer to the positions of the brightest portions of these bands. Cross-zonal measurements were not made, because the pyramidal faces were neither sufficiently numerous nor well enough developed for the purpose. The calculated values of the co-ordinate angles were determined from the same elements as in the case of the preceding crystal. It will be noticed that in the case of the one with azimuthal angle 44° 6′ the oscillation between the faces *Iy′* and *Iz′* of the twin-individuals has led to the formation of intermediate vicinal faces, the polar distances of which are 80° 27′ and 83° 40′. There is a small twinned sector on the right-hand side of the crystal in the position of the drawing; the development here is most oscillatory, but it would only have confused the drawing to have attempted to depict this feature. The pyramidal forms *Ry′* (3·2·$\bar{1}\bar{1}$) and *Ob′* (11$\bar{4}$) were not observed on the preceding crystal.

Table V. Calculated and observed values of the co-ordinate angles from (100).

Face.			Refl.	Observed.		Calculated.	
Lattice.	Symbols.	Indices.		ϕ	ρ	ϕ	ρ
	Aw′	702	f	0° 0′	16° 9′	0° 0′	15° 44′
	Ab′	101	s	,, ,,	50 9	,, ,,	50 48
		3.0.10	s	,, ,,	87 19	,, ,,	87 8
		16.0.5	b	,, ,,	17 3	,, ,,	17 15
		304	s	,, ,,	42 15	,, ,,	42 20
		105	s	,, ,,	63 6	,, ,,	63 35½
	Aa	001	s	,, ,,	74 18	,, ,,	74 28
	Ad	301	b	,, ,,	15 38	,, ,,	15 42
		207	s	,, ,,	59 31	,, ,,	59 22
		30$\bar{3}$	b	,, ,,	20 29	,, ,,	20 46
		50$\bar{3}$	b	,, ,,	33 33	,, ,,	32 55
	Ab′	10$\bar{1}$	s	,, ,,	51 6	,, ,,	50 48
III	*Ry′*	3.2.$\bar{1}\bar{1}$	b	24 10	87 10	23 58	87 39
,,	*Ob′*	11$\bar{4}$	b	30 22	85 51	30 31	85 41
,,	*Oc′*	21$\bar{4}$	b	30 30	84 13	,, ,,	82 38
II	*Jc′*	213	b	39 24	75 3	39 25	74 48
,,	*Ja*	013	b	,, ,,	76 5	,, ,,	76 23
,,	*Jb′*	11$\bar{3}$	f	,, ,,	89 11	,, ,,	89 6
,,	*Jc′*	213	f	39 26	74 46	,, ,,	74 48
,,	*Jb′*	11$\bar{3}$	f	,, ,,	89 18	,, ,,	89 6
,,	*Ix′*	525	b	44 6	64 51	44 5	64 39½
,,	*Iy′*	52$\bar{5}$	b	,, ,,	80 2	,, ,,	79 4

II	*Iz′*	125	b	44° 6′	83°40′	44° 5′	85° 0′
,,	,,	,,	b	,, ,,	84 45	,, ,,	,, ,,
,,	*Iw′*	723	b	,, ,,	53 8	,, ,,	52 59
,,	*Ix′*	523	g	,, ,,	64 41	,, ,,	64 38
,,	*Iy′*	325	b	,, ,,	78 57	,, ,,	79 4
,,	,,	,,	b	,, ,,	80 29	,, ,,	,, ,,
,,	*Hc′*	212	b	49 35	68 38	49 42	67 58½
,,	*Ha*	012	b	,, ,,	77 15	,, ,,	78 7
,,	*Hc′*	212	g	49 38	67 57	,, ,,	67 58½
,,	*Ha*	012	b	,, ,,	77 0	,, ,,	78 7
I	*Cz*	121	b	77 10	76 55	79 33	76 2
,,		910	b	89 59	14 45	90 0	15 24
,,	*Bh*	710	b	,, ,,	19 29	,, ,,	19 31
,,	*Bf*	510	b	,, ,,	26 24	,, ,,	26 23
,,	*Bd*	310	g	,, ,,	39 36	,, ,,	39 35
,,	*Bx*	520	b	,, ,,	44 40	,, ,,	44 46
,,	*Bc*	210	g	,, ,,	51 8	,, ,,	51 7
,,	*Bb*	110	b	,, ,,	68 1	,, ,,	68 2½

Crystal No. 3 (*fig.* 6).

This crystal (B.M. 1917, 400), which measures about 1 mm. in length and 2 by 1 mm. in cross-section, was acquired by Trechmann subsequent to the publication of his paper; he included it with the other crystals presented by him to the British Museum in 1917. It is noteworthy for the unusual smoothness of the prism-zone and the comparative absence of signs of distortion; on rotation of the crystal about the zone-edge when the zone was in adjustment, practically all the images crossed the field of the telescope of the goniometer accurately bisected by the horizontal wire. The measurements made in the zone are consequently exceptionally trustworthy. A face affording a sharp image of the object-slit was in the position corresponding to (10$\bar{1}$); it rarely happens that the cross-zones meet the prism-zone in faces giving such good reflections. The nearer face of the form (100) as seen in the figure, although it is step-like in character, gives an excellently defined image, the various parts being strictly parallel to one another. On the opposite side, on the other hand, the face is very narrow, being almost linear in character and the reflection is consequently faint and diffuse. The faces in the dome-zone are brilliant and relatively large. The uncommon face (010) occurs in the curious form of a bevelling of only part of the edge common to the two adjacent faces of the form *Bb*. The small triangular face alongside it gives an indistinct reflection corresponding to a face of the form (1$\bar{2}$3) in lattice II; this form has, however, not been observed on any other crystal, and it remains doubtful whether the plane is really a face of the crystal. The pyramidal faces, which, except for the one

ust referred to, occur only on the bottom right-hand corner of the rystal in the position of the figure, give mostly excellent reflections; ll the faces belong to lattice II, not a single face of the third lattice eing observed. As customary, the stippled portions of the figure ndicate broken or incompletely developed portions of the crystal.

Altogether, on the end of the crystal, observations were made of 2 dome-faces, representing 7 different forms, and of 11 pyramidal faces,

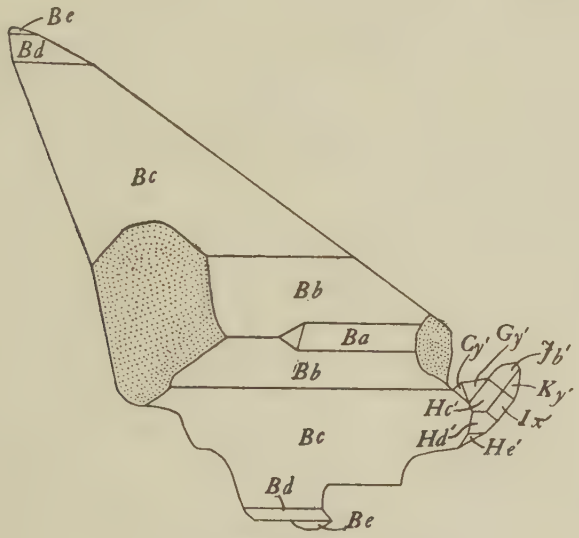

Fig. 6. Sartorite crystal No. 3.

ll belonging to different forms. The elements of the crystal and the o-ordinate angles of the various forms were computed from the following ngles:—(100) : (001) = 75° 27′ (the observed value), (100) : (101) = 37° 26′ (observed value 37° 42′; no weight was attached to this ngle because the setting was far from trustworthy), (100) : (10$\bar{1}$) = 51° 47′ he observed value), (100) : (110) = 68° 1′ (the value calculated from he measurements obtained for all the faces in the zone). The values of and *A* defining the shear are—

	f	*A*
(100) ...	0·200 ...	0·38560
(001) ...	0·150 ...	0·39074
(101) ...	0·025 ...	0·49076
(10$\bar{1}$) ...	0·175 ...	0·63434

Elements of the Lattices.

I. $a:b:c = 2{\cdot}5583:1:2{\cdot}5938$; $\beta = 104° 33'$.

II. $a:b:c = 2{\cdot}6224:1:2{\cdot}6015$;

$(010):(001) = 84° 35'$, $(001):(100) = 75° 27'$, $(100):(010) = 85° 24'$;

$\alpha = 94° 25'$, $\beta = 104° 13'$, $\gamma = 93° 23'$.

No faces belonging to the third lattice were observed.

Table VI. Calculated and observed values of the co-ordinate angles.

Face.			Refl.	Observed.		Calculated.	
Lattice.	Symbol.	Indices.		ϕ	ρ	ϕ	ρ
(a) Co-ordinates from (100)—							
	Af'	$50\bar{1}$	f	0° 0′	11° 24′	0° 0′	11° 22′
	Aw'	$70\bar{2}$	f	,, ,,	16 30	,, ,,	16 22
		$70\bar{3}$	s	,, ,,	24 38	,, ,,	24 36½
	Ay'	$30\bar{2}$	b	,, ,,	37 50	,, ,,	37 20
		$90\bar{7}$	f	,, ,,	42 27	,, ,,	42 37½
	Ab'	$10\bar{1}$	g	,, ,,	51 47	,, ,,	51 47
		$40\bar{7}$	b	,, ,,	71 50	,, ,,	71 17
	Az'	$10\bar{2}$	b	,, ,,	74 43	,, ,,	75 13
		$5{\cdot}0{\cdot}\bar{1}\bar{1}$	b	,, ,,	77 43	,, ,,	77 47½
		$20\bar{5}$	f	,, ,,	80 45	,, ,,	80 57
	Ad	301	f	,, ,,	16 59	,, ,,	16 24
		$80\bar{3}$	f	,, ,,	21 39	,, ,,	21 33
		$50\bar{3}$	b	,, ,,	26 48	,, ,,	26 31
	Ac'	$20\bar{1}$	f	,, ,,	27 30	,, ,,	28 36
	Aa	102	b	,, ,,	51 47	,, ,,	51 56
		107	s	,, ,,	68 0	,, ,,	67 45
		$5{\cdot}0{\cdot}\bar{1}\bar{1}$	g	,, ,,	77 58	,, ,,	77 47½
	Af'	$50\bar{1}$	f	,, ,,	11 32	,, ,,	11 22
		$70\bar{5}$	s	,, ,,	39 16	,, ,,	39 40
	Ab'	$10\bar{1}$	b	,, ,,	52 5	,, ,,	51 47
	Ad	301	f	,, ,,	16 50	,, ,,	16 24
		503	s	,, ,,	27 9	,, ,,	26 31
	Ab	101	s	,, ,,	35 46	,, ,,	37 26
II	Ky'	$32\bar{7}$	g	35 8	83 58	35 1½	84 16
,,	Jb'	$11\bar{3}$	g	39 4	88 55	39 1	89 10
,,	Ix'	$52\bar{5}$	g	43 55	64 44	43 51	64 49½
,,	Iy'	$32\bar{5}$	b	,, ,,	78 52	,, ,,	79 13
,,	He'	$41\bar{2}$	f	49 44	44 28	49 41½	44 30½
,,	Hd'	$31\bar{2}$	g	,, ,,	54 36	,, ,,	54 39
,,	Hc'	$21\bar{2}$	g	,, ,,	68 10	,, ,,	68 7
,,	Hb'	$11\bar{2}$	b	,, ,,	83 11	,, ,,	84 38½
,,	Gy'	$32\bar{3}$	g	56 43	72 42	56 45	72 36
,,		$12\bar{3}$	b	75 30	86 30	74 54	86 4

I	*Cy'*	$32\bar{1}$	b	79° 28′	60° 41′	79° 5′	61° 23½′
,,	*Bf*	510	f	90 0	26 21½	90 0	26 21
,,	*Bv*	920	f	,, ,,	28 44	,, ,,	28 49½
,,	*Be*	410	f	,, ,,	31 50	,, ,,	31 46
,,	*Bd*	310	f	,, ,,	39 37	,, ,,	39 33
,,	*Bc*	210	g	,, ,,	51 5	,, ,,	51 5
,,	*Bb*	110	g	,, ,,	67 59	,, ,,	68 1
,,	*Ba*	010	f	,, ,,	90 0	,, ,,	90 0
,,	*Bf*	510	f	,, ,,	26 27	,, ,,	26 21
,,	*Be*	410	f	,, ,,	31 46	,, ,,	31 46
,,	*Bd*	310	g	,, ,,	39 34	,, ,,	39 33
,,	*Bc*	210	g	,, ,,	51 1	,, ,,	51 5
,,	*Bb*	110	g	,, ,,	68 1	,, ,,	68 1
(b) Co-ordinates from (001)—							
II	*He'*	$41\bar{2}$	f	33 44	74 50	33 37	74 56
,,	*Hd'*	$31\bar{2}$	g	42 4	68 31	41 55	68 34
,,	*Ix'*	$52\bar{5}$	g	47 36	58 22	47 26½	58 20
I	*Bc*	210	g	51 58	80 54	51 59½	80 55
II	*Hc'*	$21\bar{2}$	g	54 27	60 46	54 8	60 50
,,	*Ky'*	$32\bar{7}$	g	62 30	40 23	62 11	40 13
,,	*Iy'*	$32\bar{5}$	b	,, ,,	50 0	,, ,,	50 18
,,	*Gy'*	$32\bar{3}$	g	,, ,,	64 21	,, ,,	64 27
I	*Bb*	110	g	68 40	84 38	68 39	84 36
,,	*Ba*	010	f	89 55	89 54	90 0	90 0
(c) Co-ordinates from (101)—							
II	*Ky'*	327	g	38 55	65 31	38 54	65 25
,,	*Ix'*	$52\bar{5}$	g	,, ,,	86 36	,, ,,	86 37
,,	*Hd'*	$31\bar{2}$	g	39 6	82 6	,, ,,	82 1½
I	*Bf*	510	g	,, ,,	44 45	39 11	44 38½
II	*Jb'*	$11\bar{3}$	g	45 12	62 38	45 11	62 34
,,	*Hc'*	$21\bar{2}$	g	,, ,,	85 54	,, ,,	86 2½
I	*Be*	410	b	,, ,,	47 45	45 3	47 32
II	*Hb'*	$11\bar{2}$	b	53 15	71 19	53 11	71 30
,,	*Gy'*	$32\bar{3}$	g	,, ,,	85 10	,, ,,	85 23
I	*Bd*	310	f	53 38	52 22	53 38½	52 15
,,	*Bc*	210	g	63 54	60 10	63 51½	60 5
,,	*Cy'*	$32\bar{1}$	b	,, ,,	73 18	,, ,,	73 47
,,	*Db'*	$11\bar{1}$	b	,, ,,	89 37	,, ,,	89 39
,,	*Bb*	110	g	76 14	72 44	76 13	72 42½
(d) Co-ordinates from ($10\bar{1}$)—							
II	*Ky'*	$32\bar{7}$	b	53 31	45 16	53 18	45 25
,,	*Jb'*	$11\bar{3}$	f	,, ,,	51 39	,, ,,	51 44
I	*Bc*	210	g	57 44	67 2	57 37	67 8
II	*He'*	$41\bar{2}$	f	62 30	37 4	62 22½	37 6½
,,	*Ix'*	$52\bar{5}$	g	84 28	39 2	83 40	39 7
,,	*Hc'*	$21\bar{2}$	g	,, ,,	45 26	,, ,,	45 24
,,	*Gy'*	$32\bar{3}$	g	,, ,,	53 24	,, ,,	53 24½

Crystal No. 4 (*fig.* 7).

This crystal (B.M. 83976), which measures about 1 mm. in length and 1 by 1 mm. in cross-section, was acquired by the Trustees of the British Museum in 1898. The prism-zone is of the customary grooved character and its re-entrant appearance is no doubt due to twinning;

here and there it is comparatively smooth and affords correspondingly distinct reflections. The dome-zone again is large, and the faces are smooth and give brilliant reflections. On the lower corner in the position of the figure appear a number of pyramidal faces. The curious tongue-shape of this corner will be noticed. The face Jb' has been bent parallel to the left-hand edge, and gives therefore a double image. This distortion is responsible for the shifting of the face (100) nearly a degree (0° 56′) from the position defined as the intersection of the

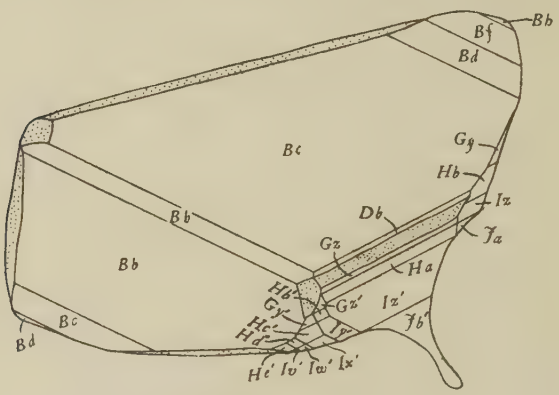

Fig. 7. Sartorite crystal No. 4.

prism- and dome-zones. The stippling indicates as usual imperfectly developed portions of the crystal. A region of this kind separates the dome-zone from the large faces of the second lattice, and may result from the shear giving rise to the latter. No face belonging to the third lattice is present. Reflections corresponding to the forms Ju', Jx' were given off the upper rounded edge of the crystal in the position of the drawing; but it is open to question whether they are genuine crystal-faces, since they have not been observed on any other crystal, and, moreover, belong not to the ordinary group—Jb, Jc, &c.—but to the intermediate one, which has seldom been observed in the case of any zone.

Altogether, on the end of the crystal, observations were made of 10 dome-faces representing 6 different forms, and of 27 pyramidal faces, representing 25 different forms. The elements of the crystal and the co-ordinate angles of the various forms were computed from the following angles:—(100):(101) = 33° 40′ (the observed value),

(100) : (10$\bar{1}$) = 52° 52′ (the observed value), (100) : (210) = 51° 2′ (the better observed value); no trustworthy setting for the pole (001) was obtainable. The values of f and A defining the shear are :—

	f	A
(100) ...	0·375 ...	0·35808
(001) ...	0·085 ...	0·37876
(101) ...	0·230 ...	0·44832
(10$\bar{1}$) ...	0·145 ...	0·64474

Elements of the Lattices.

I. $a : b : c = 2{\cdot}6395 : 1 : 2{\cdot}7929$; $\beta = 110° 25′$.

II. $a : b : c = 2{\cdot}6433 : 1 : 2{\cdot}8176$;
(010) : (001) = 82° 31′, (001) : (100) = 69° 35′, (100) : (010) = 89° 71′;
$\alpha = 97° 39′$, $\beta = 110° 29′$, $\gamma = 91° 51′$.

Table VII. Calculated and observed values of the co-ordinate angles.

Face.				Observed.		Calculated.	
Lattice.	Symbol.	Indices.	Refl.	ϕ	ρ	ϕ	ρ
(a) Co-ordinates from (100)—							
	Ad	301	b	0° 0′	14° 10′	0° 0′	14° 54′
	Ac	201	s	,, ,,	21 32	,, ,,	20 49
		40$\bar{5}$	s	,, ,,	61 59	,, ,,	62 1
	Aa	001	s	,, ,,	70 17	,, ,,	69 35½
	Ay′	30$\bar{2}$	g	,, ,,	36 41	,, ,,	37 6½
		40$\bar{3}$	b	,, ,,	40 26	,, ,,	41 25
		90$\bar{7}$	b	,, ,,	42 43	,, ,,	42 48
		10$\bar{1}$	f	,, ,,	53 13	,, ,,	52 52
		10$\bar{3}$	f	,, ,,	81 27	,, ,,	81 45
		30$\bar{4}$	b	,, ,,	39 39	,, ,,	39 22
		10$\bar{5}$	b	,, ,,	82 40	,, ,,	81 41
		10$\bar{3}$	f	,, ,,	89 27	,, ,,	89 45
		100	g	,, ,,	0 56	,, ,,	0 0
	Aw′	70$\bar{2}$	s	,, ,,	15 50	,, ,,	15 36
	Ad′	30$\bar{1}$	f	,, ,,	18 37	,, ,,	18 21
		70$\bar{4}$	g	,, ,,	31 25	,, ,,	31 56
	Ab	101	b	,, ,,	34 19	,, ,,	33 40
		50$\bar{4}$	s	,, ,,	42 58	,, ,,	43 53
	Ab′	10$\bar{1}$	b	,, ,,	52 2	,, ,,	52 52
	Av′	90$\bar{2}$	f	,, ,,	83 1	,, ,,	83 6
		10$\bar{4}$	b	,, ,,	85 40	,, ,,	84 52
II	*Kv′*	927	b	35 0	52 0	35 47	51 55½
,,	*Ja*	013	b	39 32	75 53	39 36	75 14
,,	*Ju′*	11.2.$\bar{6}$	b	39 35	40 42	,, ,,	40 51

II	*Jd′*	31$\bar{3}$	b	39° 38′	62° 30′	39° 36′	62° 59′
,,	*Jx′*	52$\bar{6}$	b	,, ,,	69 0	,, ,,	69 9
,,	*Jb′*	11$\bar{3}$	f	,, ,,	89 53	,, ,,	89 40
,,	*Iz*	125	b	44 10	69 29	44 10	69 26
,,	*Iv′*	92$\bar{5}$	b	44 16	44 21	,, ,,	44 18
,,	*Iw′*	72$\bar{5}$	b	,, ,,	53 8	,, ,,	53 23
,,	*Ix′*	52$\bar{5}$	b	,, ,,	64 51	,, ,,	65 14
,,	*Iy′*	32$\bar{5}$	f	,, ,,	79 52	,, ,,	79 49
,,	*Iz′*	12$\bar{5}$	f	,, ,,	84 32	,, ,,	84 10
,,	*He′*	41$\bar{2}$	b	49 25	44 15	49 37	44 30
,,	*He′*	41$\bar{2}$	b	49 36	44 35	,, ,,	,, ,,
,,	*Hd′*	31$\bar{2}$	b	,, ,,	54 23	,, ,,	54 39
,,	*Hc′*	21$\bar{2}$	f	,, ,,	67 57	,, ,,	68 8½
,,	*Hb′*	11$\bar{2}$	b	,, ,,	84 14	,, ,,	84 41
,,	*Hb*	112	b	,, ,,	62 32	,, ,,	62 23½
,,	*Ha*	012	b	,, ,,	78 25	,, ,,	77 52
,,	*Gy′*	32$\bar{3}$	b	55 40	71 55	56 6½	72 1
,,	*Gy*	323	b	55 57	56 19	,, ,,	55 41
,,	*Gz*	123	b	,, ,,	71 15	,, ,,	70 52
,,	*Gz′*	12$\bar{3}$	b	,, ,,	89 50	,, ,,	89 22
I	*Db*	111	b	69 58	62 54	70 18	63 9
,,	,,	,,	b	,, ,,	63 42	,, ,,	,, ,,
,,	*Cx′*	52$\bar{1}$	b	79 0	45 50	79 51	47 5
,,	*Cy*	321	b	79 15	56 56	,, ,,	56 28
,,	*Bi*	810	g	89 53	17 4	90 0	17 10½
,,	*Bf*	510	b	,, ,,	26 1	,, ,,	26 19
,,	*Bd*	310	b	,, ,,	39 31	,, ,,	39 30
,,	*Bc*	210	g	,, ,,	51 2	,, ,,	51 2
,,	*Bb*	110	g	,, ,,	67 55	,, ,,	67 59
,,	*Bh*	710	f	90 0	19 35	,, ,,	19 27½
,,	*Bf*	510	f	,, ,,	26 23	,, ,,	26 19
,,	*Bd*	310	f	,, ,,	39 36	,, ,,	39 30
,,	*Bc*	210	g	,, ,,	51 10	,, ,,	51 2
,,	*Bb*	110	f	,, ,,	68 5	,, ,,	67 59
(b) Co-ordinates from (101)—							
II	*Jb′*	$\bar{1}$1$\bar{3}$	b	44 53	64 31	45 1	64 21
,,	*Iy′*	32$\bar{5}$	b	,, ,,	75 37	,, ,,	75 52
,,	*Hc′*	21$\bar{2}$	f	,, ,,	88 34	,, ,,	88 39½
,,	*Ja*	013	b	52 5	51 27	52 12	51 15
,,	*Iz′*	$\bar{1}$2$\bar{5}$	f	,, ,,	61 28	,, ,,	61 18½
,,	*Hb′*	$\bar{1}$1$\bar{2}$	b	,, ,,	74 3	,, ,,	73 43
,,	*Gy′*	32$\bar{3}$	b	,, ,,	88 7	,, ,,	87 53
,,	*Ha*	012	b	61 0	58 30	61 7½	58 16
I	*Bc*	210	g	65 43	58 45	65 51	58 26½
(c) Co-ordinates from (10$\bar{1}$)—							
II	*Jb′*	11$\bar{3}$	f	53 43	51 59	53 34	52 24½
,,	*Iz′*	12$\bar{5}$	f	,, ,,	59 15	,, ,,	59 30
,,	*Ha*	012	b	,, ,,	67 37	,, ,,	67 47
,,	*Gz*	123	b	,, ,,	77 6	,, ,,	77 10
I	*Bd*	310	b	46 16	62 13	45 57½	62 14
,,	*Bc*	210	g	57 28	67 36	57 11	67 41½
II	*Iy′*	32$\bar{5}$	b	67 5	47 23	67 25	47 58
,,	*Hb′*	11$\bar{2}$	b	,, ,,	55 0	,, ,,	55 14
,,	*Gz′*	12$\bar{3}$	b	,, ,,	64 0	,, ,,	64 2½
I	*Bb*	110	g	72 15	76 52	72 8	76 55
II	*Iy′*	32$\bar{3}$	b	84 39	39 15	84 39½	39 27
,,	*Hc′*	21$\bar{2}$	f	,, ,,	45 6	,, ,,	45 14½
I	*Cy′*	32$\bar{3}$	b	,, ,,	52 1	,, ,,	52 28½

Crystal No. 5 (*fig.* 8).

This crystal (Solly's No. 28; B.M. 1918, 408 (28)), which measures about 1 mm. in length and 0·7 by 0·4 mm. in cross-section, is set in a kind of alcove of sartorite, which is lined with faces very nearly in harmony with the development of the crystal. Observations were on that account rendered difficult, because in the case of many of the faces several images, often overlapping one another, were simultaneously visible in the field of the telescope of the goniometer, and in consequence of the small size of the crystal it was often not easy to determine which of the images belonged to the face under observation. On the left-hand

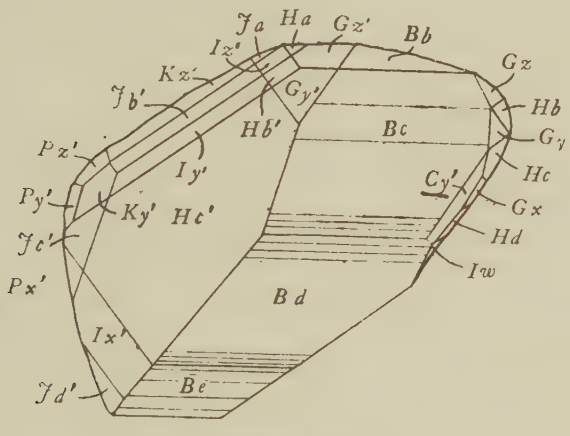

Fig. 8. Sartorite crystal No. 5.

side of the crystal, in the position of the figure, the prism-zone is only partially developed, the growth having been hindered by some foreign substance. Both for this reason and because the intrusion of the sides of the alcove prevented reflections being obtained from the parts lying back, only a limited portion of the zone was available. What reflections were given were indistinct, and some of them were spread out in a direction nearly parallel to the edge of the prism owing to the fact that the crystal is slightly distorted in the direction of the prism-edge. This zone, as usual, was used for setting up the crystal on the goniometer, the images corresponding to the part of the crystal immediately adjoining the terminal faces being selected. The adjustment was, however, not susceptible of great accuracy for the reasons stated, and the want of agreement between the observed and computed values

noticeable here and there in the table below is perhaps not surprising. Even the face (100) did not as usual yield a good measurable reflection. The most noteworthy feature of the development of the crystal is the prominence of the faces, Gy', Hc', Ix', and Jb', lying in a zone with (101); they, moreover, yielded brilliant reflections. When the crystal was first set up it was thought that this was the dome-zone, and, since this crystal was measured some time before Trechmann's No. 5, it was not for a while clear whether the crystal was sartorite or not. The dome-zone, on the other hand, is not only itself less prominent, but its faces lack some of their customary smoothness and brilliance, and are, moreover, considerably striated; measurements in this zone are therèfore unusually uncertain. A remarkable feature of the crystal is the almost complete absence of twinning about (100); of all the faces observed, only Cy' is in the twinned position.

Altogether, on the end of the crystal, observations were made of 53 faces, representing 50 different forms. Owing to the partially concealed position of the crystal, certain of the faces were not observable from (100). The elements and the co-ordinate angles of the various forms were computed from the following angles:—(100) : (001) = 72° 0′ (observed value 72° 15′), (100) : (101) = 34° 57′ (observed value 34° 47′), (100) : (10$\bar{1}$) = 52° 1′ (observed value 52° 11′), and (100) : (210) = 51° 7′ (observed value 51° 11′). The values of f and A defining the shears are—

	f	A
(100) ...	$\frac{1}{3}$ ...	0·36310
(001) ...	0 ...	0·38348
(101) ...	$\frac{1}{6}$ ...	0·46004
(10$\bar{1}$) ...	$\frac{1}{6}$ ...	0·63560

Elements of the Lattices.

I. $a : b : c = 2{\cdot}6074 : 1 : 2{\cdot}7550$; $\beta = 107° 0′$.

II. $a : b : c = 2{\cdot}6074 : 1 : 2{\cdot}7740$;
(010) : (001) = 82° 45′, (001) : (100) = 72° 0′, (100) : (010) = 87° 46′;
$\alpha = 96° 54′$, $\beta = 107° 52′$, $\gamma = 90° 0′$.

III. $a : b : c = 2{\cdot}6074 : 1 : 2{\cdot}8320$;
(010) : (001) = 75° 44′, (001) : (100) = 72° 0′, (100) : (010) = 85° 38′;
$\alpha = 103° 36′$, $\beta = 107° 29′$, $\gamma = 90° 0′$.

Table VIII. Calculated and observed values of the co-ordinate angles.

Face.			Refl.	Observed.		Calculated.	
Lattice.	Symbol.	Indices.		ϕ	ρ	ϕ	ρ
(a) Co-ordinates from (100)—							
	Ad	301	b	0° 0′	14° 53′	0° 0′	15° 2′
	Ax	502	b	,, ,,	17 45	,, ,,	17 56
	Ab	101	b	,, ,,	34 17	,, ,,	34 57
	Ay′	30$\bar{2}$	b	,, ,,	35 43	,, ,,	36 52
	Ab′	10$\bar{1}$	s	,, ,,	52 11	,, ,,	52 1
	Az′	10$\bar{2}$	b	,, ,,	75 30	,, ,,	77 9½
		30$\bar{7}$	b	,, ,,	81 25	,, ,,	81 32
		10$\bar{4}$	b	,, ,,	88 27	,, ,,	87 13
	Aa	001	b	,, ,,	72 4	,, ,,	72 0
III	*Px′*	52$\bar{9}$	b	27 35	79 10	28 3½	79 23
,,	*Pz*	12$\bar{9}$	b	27 45	68 30	,, ,,	69 7
,,	*Pz′*	12$\bar{9}$	b	,, ,,	78 33	,, ,,	79 8
,,	*Pw*	729	f	27 50	46 30	,, ,,	46 27
,,	*Px*	529	b	,, ,,	52 42	,, ,,	52 44
II	*Kx′*	527	b	36 1	71 25	35 42	72 2
,,	*Ky′*	327	f	,, ,,	84 15	,, ,,	84 55
,,	*Jd′*	313	b	39 50	62 42	39 34	62 32
,,	*Jc′*	21$\bar{3}$	f	,, ,,	74 56	,, ,,	75 15½
,,	*Jb′*	11$\bar{3}$	f	,, ,,	89 13	,, ,,	89 38
,,	*Jd*	313	b	39 40	44 35	,, ,,	44 24
,,	*Jb*	113	b	,, ,,	62 25	,, ,,	63 6
,,	*Ix′*	525	f	44 19	64 46	44 11	64 51
,,	*Iy′*	325	f	,, ,,	79 6	,, ,,	79 19
,,	*Ix*	525	b	44 31	39 0	,, ,,	39 25
,,	*Iy*	325	b	,, ,,	55 54	,, ,,	56 47½
,,	*Iz*	525	b	,, ,,	69 5	,, ,,	69 31
,,	*Hd*	312	f	49 26	41 45	49 44	41 26
,,	*Hc*	212	f	,, ,,	50 57	,, ,,	50 28
,,	*Hb*	112	b	,, ,,	62 42	,, ,,	62 37½
,,	*Ha*	012	b	,, ,,	78 11	,, ,,	78 8
,,	*Hb′*	11$\bar{2}$	b	,, ,,	84 45	,, ,,	84 25½
,,	*He′*	41$\bar{2}$	b	49 41	44 32	,, ,,	44 25
,,	*Hd′*	31$\bar{2}$	f	,, ,,	54 24	,, ,,	54 31
,,	*Hc′*	21$\bar{2}$	g	,, ,,	67 55	,, ,,	67 56
,,	*Hb′*	11$\bar{2}$	b	,, ,,	84 23	,, ,,	84 25½
,,	*Gy′*	32$\bar{3}$	f	55 42	71 46	56 21	72 5
,,	*Gz′*	12$\bar{3}$	b	,, ,,	89 35	,, ,,	89 18
,,	*Gx*	523	b	56 16	44 32	,, ,,	44 41½
,,	*Gy*	323	b	,, ,,	55 17	,, ,,	55 39
,,	*Gz*	123	b	,, ,,	70 34	,, ,,	70 49
,,	*Fc*	211	b	63 15	49 3	64 10	49 4
,,	*Fb*	111	b	,, ,,	63 43	,, ,,	63 14
,,	*Fa*	011	b	,, ,,	82 10	,, ,,	81 56½
I	*Da*	011	b	70 0	83 35	70 3	84 58
,,		144	b	,, ,,	89 35	,, ,,	89 55

I	*Dd*	311	b	70° 6′	38° 15′	70° 3′	38° 43′
,,	*Db*	111	b	,, ,,	63 25	,, ,,	63 54
,,	*Cy′*	32$\bar{1}$	b	79 40	61 52	79 43	61 46
,,	*Cx*	521	b	81 15	44 50	,, ,,	43 36
,,	*Bj*	910	s	89 42	15 25	90 0	15 24
,,	*Bg*	610	s	,, ,,	22 15	,, ,,	22 27½
,,	*Be*	410	b	,, ,,	32 20	,, ,,	31 48
,,	*Bd*	310	b	,, ,,	40 6	,, ,,	39 35
,,	*Bc*	210	g	,, ,,	51 11	,, ,,	51 7
,,	*Bb*	110	b	,, ,,	67 25	,, ,,	68 2½
,,		130	b	,, ,,	74 56	,, ,,	74 57
(b) Co-ordinates from (001)—							
I	*Be*	410	b	32 35	75 18	33 6	74 46½
III	*Pw*	729	b	36 25	35 8	36 41	34 48
II	*Iw*	725	b	,, ,,	48 21	,, ,,	47 48
,,	*Hd*	312	b	41 23	51 7	41 0	50 19
I	*Bd*	310	f	,, ,,	76 0	,, ,,	76 13
III	*Px*	529	b	46 9	31 39	46 12½	31 14
II	*Gx*	523	b	,, ,,	54 15	,, ,,	53 52
III	*Px′*	52$\bar{9}$	b	46 26	40 2	,, ,,	39 46½
II	*Kx′*	527	b	,, ,,	51 0	,, ,,	50 10½
,,	*Ix′*	52$\bar{5}$	g	,, ,,	61 1	,, ,,	60 49
,,	*Hc*	212	b	52 33	47 39	52 31	47 52
,,	*Fc*	211	b	,, ,,	58 30	,, ,,	58 58
I	*Bc*	210	g	,, ,,	78 34	,, ,,	78 49
II	*Jc′*	21$\bar{3}$	f	52 40	51 17	,, ,,	50 51
,,	*Hc′*	21$\bar{2}$	g	,, ,,	63 0	,, ,,	62 56
,,	*Ky′*	327	b	59 23	42 11	60 5½	42 4
,,	*Iy′*	32$\bar{5}$	f	,, ,,	51 52	,, ,,	52 9
,,	*Gy′*	323	g	,, ,,	65 29	,, ,,	65 57½
,,	*Jb*	113	b	67 53	38 20	69 1	37 28½
,,	*Hb*	112	b	,, ,,	47 0	,, ,,	46 32
,,	*Fb*	111	b	,, ,,	60 0	,, ,,	59 23½
I	*Db*	111	b	,, ,,	65 23	,, ,,	64 42
,,	*Bb*	110	f	,, ,,	83 23	,, ,,	83 22
II	*Jb′*	113	f	68 31	42 55	,, ,,	43 0
,,	*Hb′*	112	f	,, ,,	53 54	,, ,,	54 24
III	*Pz′*	129	f	78 42	27 41	79 9	28 3½
II	*Iz′*	125	b	,, ,,	44 55	,, ,,	44 58
,,	*Gz′*	123	b	,, ,,	56 30	,, ,,	57 56½
,,	*Gz*	123	b	80 15	54 15	,, ,,	53 11
I	*Cz*	121	b	,, ,,	75 50	,, ,,	76 2
II	*Ha*	012	f	89 32	47 52	90 0	48 16
,,	*Fa*	011	b	,, ,,	68 50	,, ,,	69 6
(c) Co-ordinates from (101)—							
III	*Pz′*	12$\bar{9}$	f	36 38	49 47	37 30	50 26
II	*Hd′*	31$\bar{2}$	b	38 45	79 35	39 11	80 4
,,	*Ix′*	52$\bar{5}$	f	,, ,,	88 55	,, ,,	88 31
,,	*Ky′*	32$\bar{7}$	f	39 14	68 9	,, ,,	66 49½
,,	*Jc′*	21$\bar{3}$	f	,, ,,	78 13	,, ,,	77 13
III	*Pz*	129	b	42 1	40 26	42 58	41 0
II	*Jb′*	11$\bar{3}$	f	45 3	65 4	45 5½	63 58
,,	*Iy′*	32$\bar{5}$	f	,, ,,	76 6	,, ,,	75 15½
,,	*Hc′*	21$\bar{2}$	g	,, ,,	88 24	,, ,,	87 50½
I	*Be*	310	b	47 31	45 45	47 23	45 47½
II	*Iz′*	125	b	52 27	61 27	52 31	60 53
,,	*Hb′*	11$\bar{2}$	b	,, ,,	73 58	,, ,,	73 4

II	*Gy′*	323	f	52° 27′	87° 38′	52° 31′	87° 31½′
I	*Bd*	310	b	55 35	50 29	55 23½	50 47
III	*Px*	529	b	57 30	25 56	58 28½	25 59
I	*Bc*	210	g	65 30	58 31	65 18	59 1
III	*Pw*	729	b	68 15	21 30	69 1	21 26½
II	*Iy*	325	b	72 13	37 35	72 27	37 35
,,	*Hb*	112	b	,, ,,	45 10	,, ,,	45 7
,,	*Gz*	123	b	,, ,,	55 17	,, ,,	55 18
,,	*Fa*	011	b	,, ,,	68 40	,, ,,	68 44½
,,	*Iw*	725	b	81 15	26 35	81 16	26 33½
,,	*Hd*	312	f	,, ,,	30 46	,, ,,	30 41
,,	*Gx*	523	b	,, ,,	36 12	,, ,,	36 6
,,	*Fc*	211	b	,, ,,	43 22	,, ,,	43 26
,,	*Hc*	212	b	85 0	35 58	85 36	36 6
,,	*Gy*	323	b	,, ,,	43 25	,, ,,	43 30
,,	*Fb*	111	b	,, ,,	53 42	,, ,,	53 38
I	*Db*	111	b	90 0	57 20	90 0	57 32
d) Co-ordinates from (10$\bar{1}$)—							
III	*Pw*	729	b	20 11	85 38	19 53	85 22
,,	*Px*	529	b	22 30	80 0	22 14	79 36
,,	*Pz*	129	b	28 47	64 8	28 53	64 39
II	*Hd*	312	b	30 30	82 20	30 23½	82 59
III	*Pz′*	529	b	33 48	55 1	33 49	55 41
II	*Jb*	113	b	35 50	75 0	35 47	74 48
,,	*Iy*	325	b	,, ,,	82 35	,, ,,	82 12
,,	*Gx*	523	b	36 7	82 0	,, ,,	82 27
,,	*Hc*	212	b	,, ,,	89 37	,, ,,	89 52
,,	*Iz*	125	b	43 30	71 15	43 55	71 22
,,	*Hb*	112	b	,, ,,	78 30	,, ,,	80 7½
,,	*Iz*	125	b	43 50	72 0	,, ,,	71 32
,,	*Hb*	112	b	,, ,,	80 45	,, ,,	80 7½
,,	*Gy*	323	b	,, ,,	89 35	,, ,,	89 11
I	*Bd*	310	g	46 6	61 31	46 22	61 41
II	*Ha*	012	b	53 55	67 50	53 26½	68 11½
,,	*Gz*	123	b	,, ,,	77 51	,, ,,	77 51½
,,	*Fb*	111	b	,, ,,	88 10	,, ,,	88 16½
,,	*Lc′*	21$\bar{4}$	b	54 44	36 55	,, ,,	37 2
,,	*Ky′*	327	b	,, ,,	45 51	,, ,,	46 19
,,	*Jb′*	11$\bar{3}$	f	,, ,,	52 3	,, ,,	52 24
,,	*Iz′*	125	b	,, ,,	59 10	,, ,,	59 40
,,	*Ha*	012	b	,, ,,	67 25	,, ,,	68 11½
,,	*Gz*	123	b	,, ,,	77 45	,, ,,	77 51½
I	*Bc*	210	f	57 15	67 40	57 33½	67 21
,,	*Db*	111	b	57 30	87 25	,, ,,	88 22
III	*Kx′*	52$\bar{7}$	b	67 41	36 7	67 2	37 5½
,,	*Jc′*	21$\bar{3}$	b	,, ,,	41 59	,, ,,	42 0
,,	*Iy′*	32$\bar{5}$	f	,, ,,	48 1	,, ,,	48 4
,,	*Hb′*	11$\bar{2}$	b	,, ,,	55 30	,, ,,	55 32
,,	*Gz′*	12$\bar{3}$	b	,, ,,	64 45	,, ,,	64 38
,,	*Fa*	011	b	,, ,,	86 50	,, ,,	87 8
I	*Bb*	110	b	71 36	75 39	72 19	76 45
III	*Hd′*	31$\bar{2}$	b	77 39	38 44	78 2	39 30½
,,	*Jd′*	31$\bar{3}$	b	84 16	34 50	83 57	34 48
,,	*Ix′*	52$\bar{5}$	g	,, ,,	39 31	,, ,,	39 26
,,	*Hc′*	21$\bar{2}$	g	,, ,,	45 24	,, ,,	45 22½
,,	*Gy′*	32$\bar{3}$	f	,, ,,	52 51	,, ,,	52 50
,,	*Fb′*	11$\bar{1}$	b	,, ,,	73 11	,, ,,	73 18½

Crystal No. 6 (fig. 9).

This crystal (Solly's No. 24; B.M. 1918, 408 (24)), measures 2·6 mm in length and 1·7 by 1·2 mm. in section. The dome-zone is of unusually large relative size, and the faces are conspicuously bright and smooth. Into the large face *Bc* runs a cleft which is bounded on the farther side in the position of the figure by the face *Bd* and at the sides by some irregular growth. The same sort of hump-like growth occurs on the

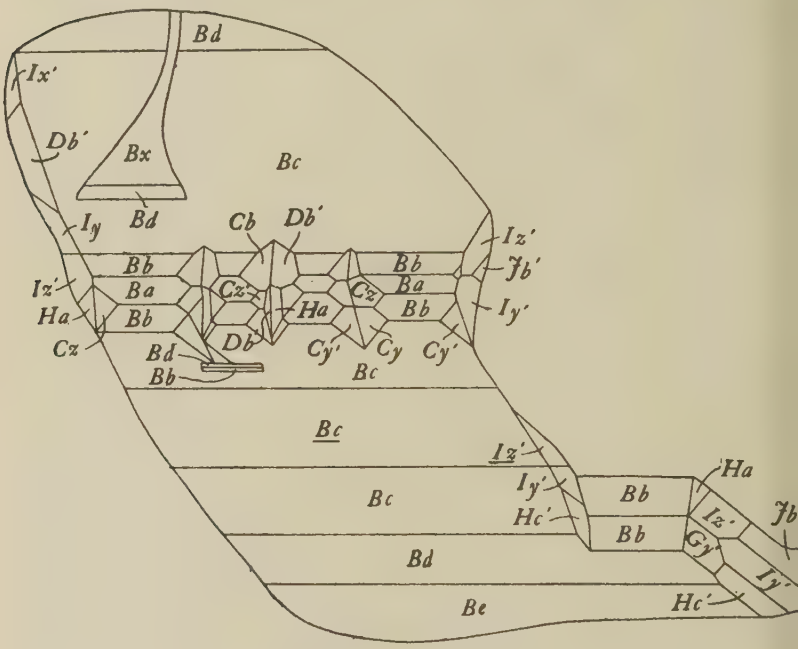

Fig. 9.—Sartorite crystal No. 6.

top as was noted in the case of Trechmann's crystal No. 5 (p. 274). A usual, the crystal is twinned, a small twin section running from side t side just below the hump-like growth referred to. As is often the cas the growth of the prism-zone has been interfered with and the edg bounding the various little faces are slightly tilted towards one anoth on opposite sides of the crystal; in consequence it is not possible adjust the crystal so that all the reflected images given by this zone c rotation of the crystal traverse centrally the horizontal wire in th

ye-piece of the telescope of the goniometer, and the positions of the oles determined by the intersections of cross-zones must necessarily e a little uncertain. Of the faces of the form (100) the near one in ie figure gives a distinct reflection despite the oscillatory and step-like naracter; the parallel one on the other side of the crystal affords a far ss satisfactory reflection.

Altogether, on the end of the crystal, were observed the pinacoid of mmetry, 9 dome-faces representing 6 different forms, and 28 pyramidal es representing 17 different forms. The elements and co-ordinate gles of the various forms were computed from the following angles:— 00):(001) = 75° 1′ (the observed value), (100):(101) = 36° 39′ bserved value 36° 40′), (100):(10$\bar{1}$) = 51° 2′ (the observed value), d (100):(210) = 50° 55′ (the most trustworthy observed value). The lues of f and A defining the shear are:—

	f	A
(100) ...	0·24 ...	0·37724
(001) ...	0·16 ...	0·39225
(101) ...	0·04 ...	0·48478
(10$\bar{1}$) ...	0·20 ...	0·63144

one of the faces referable to the third lattice were observed. It will noticed that the corresponding faces on different lattices are on this ystal very nearly in the same zone with the pole (101).

Elements of the Lattices.

I. $a:b:c = 2{\cdot}5495:1:2{\cdot}6511$; $\beta = 104° 59′$.

II. $a:b:c = 2{\cdot}5544:1:2{\cdot}6624$;

(010):(001) = 83° 42½′, (001):(100) = 75° 1′, (100):(010) = 84° 55½′;

$\alpha = 95° 10½′$, $\beta = 104° 34′$, $\gamma = 93° 35½′$.

Table IX. Calculated and observed values of the co-ordinate angles.

Face.			Refl.	Observed.		Calculated.	
Lattice.	Symbol.	Indices.		ϕ	ρ	ϕ	ρ
(a) Co-ordinates from (100)—							
	Ad	301	b	0° 0′	16° 35′	0° 0′	15° 57½′
		503	b	,, ,,	25 55	,, ,,	25 52½
		705	b	,, ,,	29 23	,, ,,	29 24
		708	b	,, ,,	39 40	,, ,,	39 35
		103	s	,, ,,	57 0	,, ,,	57 56
	Af	501	b	,, ,,	9 32	,, ,,	10 2
		703	b	,, ,,	19 38	,, ,,	19 47
		103	b	,, ,,	58 7	,, ,,	57 56
		105	b	,, ,,	64 10	,, ,,	64 13
		407	f	,, ,,	71 49	,, ,,	70 50
		103	s	,, ,,	84 0	,, ,,	84 47½
		705	b	,, ,,	29 45	,, ,,	29 24
		708	b	,, ,,	39 7	,, ,,	39 35
		3·0.11	b	,, ,,	60 38	,, ,,	60 42
		407	b	,, ,,	71 11	,, ,,	70 50
	Ae	401	b	,, ,,	11 46	,, ,,	12 20
		10.0·3	b	,, ,,	16 46	,, ,,	16 46
		703	b	,, ,,	19 39	,, ,,	19 47
		704	b	,, ,,	24 47	,, ,,	24 56
	Ay′	30$\bar{2}$	b	,, ,,	37 10	,, ,,	36 35
		203	b	,, ,,	44 45	,, ,,	45 25½
	Ab′	10$\bar{1}$	b	,, ,,	51 37	,, ,,	51 2
II	*Jb′*	113	f	39 24	89 7	39 17	89 29½
,,	*Ix′*	52$\bar{5}$	f	43 55	65 0	44 3	64 54½
,,	*Iy′*	32$\bar{5}$	f	,, ,,	79 25	,, ,,	79 28
,,	*Iz′*	12$\bar{5}$	f	,, ,,	84 50	,, ,,	84 30
,,	,,	,,	b	44 0	84 54	,, ,,	,, ,,
,,	*Iy′*	32$\bar{5}$	f	44 10	79 10	,, ,,	79 28½
,,	*Iz′*	12$\bar{5}$	b	,, ,,	85 35	,, ,,	84 30½
,,	*Hc′*	21$\bar{2}$	f	49 45	68 19	49 48	68 18
,,	*Hb′*	11$\bar{2}$	b	,, ,,	84 15	,, ,,	84 59
,,	*Ha*	012	b	,, ,,	77 52	,, ,,	77 28
,,	*Hb′*	11$\bar{2}$	b	,, ,,	84 35	,, ,,	84 59
,,	*Hc′*	21$\bar{2}$	b	49 49	68 19	,, ,,	68 18
,,	*Hb′*	11$\bar{2}$	b	,, ,,	84 38	,, ,,	84 59
,,	*Hc′*	21$\bar{2}$	b	49 50	68 38	,, ,,	68 18
,,	*Ha*	012	b	,, ,,	77 50	,, ,,	77 28
,,	*Hb′*	11$\bar{2}$	b	,, ,,	84 53	,, ,,	84 59
,,	*Gz′*	123	b	56 46	88 36	56 43	88 12
,,	*Gy′*	32$\bar{3}$	b	56 47	72 40	,, ,,	72 53
,,	*Fb′*	11$\bar{1}$	b	65 40	79 0	64 56	78 56
I	*Lb′*	11$\bar{1}$	b	68 37	74 16	69 20	74 4
,,	*Da*	011	b	68 42	84 50	,, ,,	84 36
,,	*Db′*	11$\bar{1}$	b	68 44	74 8	,, ,,	74 4
,,	*Cz′*	12$\bar{1}$	b	78 52	81 4	79 19	81 28

I	*Cy*	321	b	79° 9′	57° 7′	79° 19′	57° 3′
,,	*Cz*	121	f	,, ,,	76 8	,, ,,	76 1
,,	*Cx*	52$\bar{1}$	b	,, ,,	46 40	,, ,,	46 32
,,	*Cy*	321	b	79 14	57 15	,, ,,	57 3
,,	*Cy′*	32$\bar{1}$	b	,, ,,	61 24	,, ,,	61 14
,,	*Cz*	121	f	79 15	76 15	,, ,,	76 1
,,	*Be*	410	f	90 0	31 40	90 0	31 37
,,	*Bd*	310	f	,, ,,	39 26	,, ,,	39 23
,,	*Bc*	210	g	,, ,,	50 55	,, ,,	50 55
,,	,,	,,	f	,, ,,	50 57	,, ,,	,, ,,
,,	*Bb*	110	f	,, ,,	67 50	,, ,,	67 54
,,	*Bd*	310	b	,, ,,	39 15	,, ,,	39 23
,,	*Bx*	520	f	,, ,,	44 35	,, ,,	44 34
,,	*Bc*	210	g	,, ,,	50 53	,, ,,	50 55
,,	*Bb*	110	f	,, ,,	67 50	,, ,,	67 54
,,	*Ba*	010	b	,, ,,	90 0	,, ,,	90 0
(b) Co-ordinates from (001)—							
I	*Be*	410	g	32 30	77 19	32 31	77 17
,,	,,	,,	g	,, ,,	77 28	,, ,,	,, ,,
,,	*Bd*	310	g	40 25	78 32	40 21½	78 28
,,	,,	,,	g	,, ,,	78 40	,, ,,	,, ,,
,,	*Bx*	520	g	45 54	79 39	45 34	79 23
,,	*Bc*	210	g	51 57	80 47	51 53	80 37
,,	,,	,,	g	52 15	80 48	,, ,,	,, ,,
II	*Hc′*	21$\bar{2}$	b	54 5	60 47	54 11	61 4½
,,	,,	,,	f	54 26	60 56	,, ,,	,, ,,
,,	*Iy′*	32$\bar{5}$	f	62 2	50 37	62 16	50 34
,,	*Gy′*	32$\bar{3}$	b	,, ,,	64 26	,, ,,	64 30
,,	*Iy′*	32$\bar{5}$	b	62 27	50 25	,, ,,	50 34
I	*Bb*	110	f	68 33	84 31	68 35	84 25
,,	,,	,,	b	68 36	84 25	,, ,,	,, ,,
,,	*Db′*	11$\bar{1}$	g	68 45	74 45	,, ,,	75 7
,,	*Bb*	110	f	,, ,,	84 24	,, ,,	84 25
,,	,,	,,	f	68 36	84 29	,, ,,	,, ,,
,,	*Cz*	121	f	79 8	76 10	78 54	76 20
,,	,,	,,	f	79 26	76 9	,, ,,	,, ,,
II	*Iz′*	12$\bar{5}$	f	82 2	44 17	82 24	44 17
,,	*Ha*	012	b	87 0	48 22	86 24	48 20
,,	,,	,,	f	87 10	48 17	,, ,,	,, ,,
(c) Co-ordinates from (101) —							
II	*Ix′*	52$\bar{5}$	b	39 6	86 52½	39 5	87 14
,,	*Jb′*	11$\bar{3}$	f	45 19	63 15	45 19	62 57
,,	*Iy′*	32$\bar{5}$	b	,, ,,	74 13	,, ,,	74 2
,,	*Hc′*	21$\bar{2}$	b	,, ,,	86 20	,, ,,	86 29
,,	*Jb′*	11$\bar{3}$	b	45 25	62 26	,, ,,	62 57
,,	*Iy′*	32$\bar{5}$	f	,, ,,	73 53	,, ,,	74 2
,,	*Hc′*	21$\bar{2}$	f	,, ,,	86 19	,, ,,	86 29
I	*Be*	410	g	45 47	47 3	45 53	46 54½
II	*Iz′*	12$\bar{5}$	b	53 17	59 54	53 15	59 44½
,,	*Gy′*	32$\bar{3}$	b	,, ,,	85 37	,, ,,	85 35½
,,	*Iz′*	12$\bar{5}$	b	,, ,,	60 1	,, ,,	59 44½
,,	*Hb′*	11$\bar{2}$	b	,, ,,	71 50	,, ,,	71 43½
,,	*Gy′*	32$\bar{3}$	b	,, ,,	84 57	,, ,,	85 35½
I	*Bd*	310	g	53 54	51 56	53 59	51 40
,,	,,	,,	g	53 59	51 50	,, ,,	,, ,,
II	*Ha*	012	b	63 10	56 51	63 15	56 37
,,	,,	,,	f	63 15	56 55	,, ,,	,, ,,

I	*Db′*	11$\bar{1}$	b	63°	42′	89°	25′	64°	8′	88°	59′
,,	,,	,,	f	64	9	89	21	,,	,,	,,	,,
,,	*Bc*	210	g	64	11	59	45	,,	,,	59	37
,,	*Cy′*	32$\bar{1}$	f	,,	,,	73	27	,,	,,	73	12
,,	*Bc*	210	g	64	17	60	0	,,	,,	59	37
,,	*Da*	011	b	76	8	73	23	76	22½	73	26
,,	*Bb*	110	b	76	18	72	15	,,	,,	72	26
,,	,,	,,	f	76	31	72	24	,,	,,	,,	,,
,,	*Cx*	521	f	89	35	72	19	90	0	72	28
,,	,,	,,	f	89	56	72	40	,,	,,	,,	,,
(d) Co-ordinates from (10$\bar{1}$)—											
I	*Be*	410	g	38	55	57	35	38	22½	57	37
,,	,,	,,	g	,,	,,	57	46	,,	,,	,,	,,
,,	*Bd*	310	f	46	47	60	59	46	33	60	55
,,	,,	,,	f	47	1	61	4	,,	,,	,,	,,
,,	,,	,,	f	,,	,,	61	12	,,	,,	,,	,,
II	*Ha*	012	f	53	10	52	58	52	51	52	36
,,	*Iz′*	125	b	,,	,,	60	39	,,	,,	60	16
,,	*Jb′*	113	f	,,	,,	69	43	,,	,,	69	18
,,	*Ix′*	525	b	53	14	60	17	,,	,,	60	16
,,	*Jb′*	113	b	,,	,,	69	15	,,	,,	69	18
I	*Bc*	210	f	58	4	66	58	57	44	66	38½
,,	,,	,,	g	58	5	66	51	,,	,,	,,	,,
II	*Iy′*	325	b	66	6	48	25	66	9	48	22
,,	,,	,,	b	66	29	48	48	,,	,,	,,	,,
,,	*Hb′*	112	b	,,	,,	56	46	,,	,,	56	18
I	*Bb*	110	b	72	34	76	23	72	29	76	19
,,	*Cz*	121	f	,,	,,	89	47	,,	,,	89	21
,,	,,	,,	f	72	40	89	21	,,	,,	,,	,,
,,	*Bb*	110	f	72	42	76	5	,,	,,	76	19
,,	*Cy′*	32$\bar{1}$	f	72	56	64	52	,,	,,	64	36
II	*Hc′*	113	b	82	35	39	23	82	48	39	24
,,	*Ix′*	525	b	,,	,,	45	48	,,	,,	45	50
,,	,,	,,	b	82	54	46	8	,,	,,	,,	,,
,,	*Gy′*	323	b	,,	,,	54	1	,,	,,	53	58

Other Crystals.

Nineteen of the remaining measured crystals showed pyramidal faces, though neither sufficiently numerous nor well enough developed for the cross-zonal relations to be determined. These crystals comprised fourteen in R. H. Solly's collection (B.M. 1918, 408), namely, those numbered 11 (a), 11 (b), 14, 15, 20, 21, 23, 25, 28 (b), 44, 54, 58, 59, 60; and five formerly in C. O. Trechmann's collection, namely, the one numbered 7 in his memoir,[1] and four other, the several pairs being numbered 1917, 395, and 1917, 399, in the British Museum Register of Accessions. A few additional forms on the end of the crystals were noted, namely, two pyramidal forms *Iu* (11·2·5) and *Jz* (126) each of which was represented by a single tiny face giving a faint and ill-defined

[1] Loc. cit., pp. 214, 225, 226.

flection and is rather doubtful, and fifteen dome-forms—(23.1.0), 6.1.0), *Bl* (11.1.0), *Bk* (10.1.0), *Br* (17.2.0), *Bg* (610), (16.3.0), 1.6.0), *Bw* (720), (830), (13.6.0), (11.7.0), (760), (570), (15.8.0). wing to the striated character of the prism-zone and the con-quent banded nature of the reflections, readings in this zone were ry uncertain. It will be noticed from the table that reflections were t with almost continuously through a right angle from the origin of asurement, or, in other words, through the whole of the zone. The uping of the angles as given in the table was therefore to some tent arbitrary, but as far as possible thick clusters of readings were ught together. The values given in the column of calculated angles those computed on the data found for Crystal No. 1 above (p. 278); e nearest concordant pole with simple indices, whether positive or gative, was entered in the column.

Table X. List of forms observed on 19 *other crystals and the corresponding co-ordinate angles from* (100).

Face.	Indices.	Observed Means.		Limits of Observations.		No.	Calculated.	
		ϕ	ρ	ϕ	ρ		ϕ	ρ
″	$90\bar{1}$	0° 0′	5° 48′			1	0° 0′	5° 58′
′	$70\bar{1}$	,, ,,	7 32			1	,, ,,	7 43
′	$60\bar{1}$	,, ,,	9 17			1	,, ,,	9 3
″	902						,, ,,	10 53
″	$50\bar{1}$						,, ,,	10 54½
″	401	,, ,,	11 44	10 28 – 13 37		14	,, ,,	12 8
″	$90\bar{2}$						,, ,,	12 9
″	702						,, ,,	13 41½
″	$40\bar{1}$						,, ,,	13 43
″	301	,, ,,	15 50	14 7 – 17 5		20	,, ,,	15 42
′	$70\bar{2}$						,, ,,	15 44
″	502	,, ,,	18 26	17 46 – 19 12		16	,, ,,	18 22
′	$30\bar{1}$						,, ,,	18 25½
	$80\bar{3}$	,, ,,	20 25	19 56 – 21 23		6	,, ,,	20 45½
	201	,, ,,	22 22	22 0 – 22 33		5	,, ,,	22 5
′	$50\bar{2}$						,, ,,	22 9½
	905						,, ,,	24 0
	704	,, ,,	24 33	23 6 – 25 51		13	,, ,,	24 32
	503						,, ,,	25 27½
	805						,, ,,	26 15
	302	,, ,,	27 7	26 39 – 27 40		3	,, ,,	27 32
″	$20\bar{1}$						,, ,,	27 39
	905	,, ,,	30 28	29 40 – 31 18		7	,, ,,	30 36

	$70\bar{4}$								0° 0′	31°2′	
	605	0° 0′	32° 33′			31 53 – 32 55	10	,, ,,	32 1		
	503							,, ,,	32 5		
Ab	101	,, ,,	36 7			35 34 – 38 15	8	,, ,,	36		
Ay′	$30\bar{2}$							,, ,,	36 1		
	506	,, ,,	40 0				1	,, ,,	40		
	405	,, ,,	40 50				1	,, ,,	40 5		
	304	,, ,,	42 21			41 43 – 42 50	15	,, ,,	42 2		
	$50\bar{4}$							,, ,,	42 3		
	$60\bar{5}$	,, ,,	44 14			44 10 – 44 18	2	,, ,,	44		
	203	,, ,,	44 48				1	,, ,,	44 4		
	$90\bar{8}$	,, ,,	46 30				1	,, ,,	46 2		
	407	,, ,,	47 38			47 13 – 48 7	3	,, ,,	47 5		
Az	102							,, ,,	50 2		
Ab′	$10\bar{1}$	,, ,,	50 41			48 43 – 52 9	23	,, ,,	50 4		
	307	,, ,,	53 49			53 0 – 54 31	7	,, ,,	53 1		
	$70\bar{8}$	,, ,,	55 49			55 41 – 55 57	2	,, ,,	55 4		
	$40\bar{5}$	,, ,,	59 6			58 19 – 59 55	9	,, ,,	59 1		
	104	,, ,,	61 17				1	,, ,,	61		
	$30\bar{4}$	,, ,,	61 35				1	,, ,,	61 3		
	209	,, ,,	62 21					,, ,,	62 2		
	507	,, ,,	63 19			63 2 – 63 49	3	,, ,,	63 1		
	106	,, ,,	65 8				1	,, ,,	65 1		
	$30\bar{5}$	,, ,,	68 17			68 33 – 68 57	3	,, ,,	68 1		
	407	,, ,,	71 6			70 14 – 72 52	5	,, ,,	70 5		
Aa	001	,, ,,	75 33			74 45 – 76 16	3	,, ,,	74 2		
Az′	$10\bar{2}$							,, ,,	74 5		
	$20\bar{5}$	,, ,,	80 40			77 57 – 82 16	11	,, ,,	80 5		
	$10\bar{3}$	,, ,,	85 41			83 0 – 87 14	15	,, ,,	85 2		
	$\bar{1}04$	,, ,,	89 16			89 8 – 89 24	2	,, ,,	89 4		
Pw′	$72\bar{9}$	28 2	69 34	27 48 – 28 13		69 28 – 69 40	2	28 0	69 1		
Px′	$52\bar{9}$	,, ,,	79 27			79 12 – 79 42	2	,, ,,	79 1		
Od′	$31\bar{4}$	30 29	72 35				1	30 31	71 5		
Oc′	$21\bar{4}$	,, ,,	84 49				1	,, ,,	82 3		
Jz	126	39 39	71 10	39 18 – 40 17			1	39 25	69 4		
Ja	013	,, ,,	75 57			75 30 – 76 15	3	,, ,,	76 2		
Jb′	$11\bar{3}$	,, ,,	89 12			88 5 – 90 0	8		89		
Iu	11.2.5	44 6	28 22	43 12 – 45 29			1	44 5	29 2		
Iw	725	,, ,,	39 30				1	,, ,,	39 3		
Iv′	$92\bar{5}$	,, ,,	44 35				1	,, ,,	44		
Ix	525	,, ,,	46 58				1	,, ,,	47		
Iy	325	,, ,,	57 3				1	,, ,,	57		
Ix′	$52\bar{5}$	,, ,,	64 42			64 4 – 65 10	10	,, ,,	64 3		
Iz	125	,, ,,	69 40			69 10 – 69 59	11	,, ,,	69 4		
Iy′	$32\bar{5}$	,, ,,	79 25			78 52 – 80 5	11	,, ,,	79		
Iz′	$12\bar{5}$	,, ,,	84 49			84 10 – 85 32	17	,, ,,	85		
Hd	312	49 $45\frac{1}{2}$	41 30	48 54 – 51 15			2	49 42	41 2		
He′	$41\bar{2}$	,, ,,	44 40			48 36 – 45 49	9	,, ,,	44 2		
Hc	212	,, ,,	50 29			50 11 – 50 47	2	,, ,,	50 2		
Hd′	$31\bar{2}$	,, ,,	54 36			54 15 – 55 18	9	,, ,,	54 3		
Hb	112	,, ,,	62 45			62 33 – 62 57	2	,, ,,	62 3		
Hc′	$21\bar{2}$	,, ,,	68 4			67 29 – 68 58	26	,, ,,	67 5		
Ha	012	,, ,,	77 $52\frac{1}{2}$			77 10 – 78 30	10	,, ,,	78		
Hb′	$11\bar{2}$	,, ,,	84 34			84 9 – 85 30	7	,, ,,	84 2		
Gw′	$72\bar{3}$	56 24	47 59	56 3 – 57 30			1	56 26	45 2		
Gz	123	,, ,,	69 29				1	,, ,,	70 2		
Gy′	$32\bar{3}$	,, ,,	72 $24\frac{1}{2}$			71 52 – 73 8	4	,, ,,	72 2		
Gz′	$\bar{1}23$	,, ,,	89 41			89 30 – 89 52	2	,, ,,	88		
Fc	211	63 58	50 7	63 30 – 64 40			1	64 24	48		

Fc′	$21\bar{1}$	63°58′	60° 5′		59 5 – 61 5	2	64°24′	60°17′
Db′	$11\bar{1}$	70 27	74 37	69 40 – 71 15	73 32 – 75 42	2	69 45½	74 14½
	$\bar{1}44$	,, ,,	89 55			1	,, ,,	89 55
Cx	521	79 19	43 48	78 38 – 80 12		1	79 33	43 50
Cx′	$52\bar{1}$	,, ,,	46 44		46 39 – 47 1	3	,, ,,	46 45½
Cy	321	,, ,,	56 55		56 37 – 57 28	5	,, ,,	57 10
Cy′	$32\bar{1}$	,, ,,	61 30		60 15 – 62 6	7	,, ,,	61 25½
Cz	121	,, ,,	76 8		75 50 – 76 26	2	,, ,,	76 2
Cz′	$12\bar{1}$	,, ,,	82 2			1	,, ,,	81 35
	23.1.0	90 0	6 7	89 22		1	90 0	6 9
	16.1.0	,, ,,	8 58			1	,, ,,	8 49
Bl	11.1.0	,, ,,	12 34		12 28 – 12 44	5	,, ,,	12 42
Bk	10.1.0	,, ,,	13 52		13 44 – 13 58	5	,, ,,	13 56
Bj	9.1.0	,, ,,	15 21½		15 14 – 15 30	6	,, ,,	15 24
Br	17.2.0	,, ,,	16 29		16 26 – 16 32	2	,, ,,	16 16
Bi	810	,, ,,	17 14		17 6 – 17 21	5	,, ,,	17 13½
Bh	710	,, ,,	19 32		19 21 – 19 45	8	,, ,,	19 30½
Bt	13.2.0	,, ,,	21 12			1	,, ,,	20 53
Bg	610	,, ,,	22 26		22 20 – 22 30	7	,, ,,	22 27½
	16.3.0	,, ,,	24 50		24 46 – 24 56	3	,, ,,	24 56½
	31.6.0	,, ,,	25 43		25 20 – 25 56	4	,, ,,	25 38½
Bf	510	,, ,,	26 28		26 14 – 27 4	17	,, ,,	26 23
Bv	920	,, ,,	28 56			1	,, ,,	28 52
Be	410	,, ,,	31 45		31 14 – 32 4	15	,, ,,	31 48
Bw	720	,, ,,	35 34		35 23 – 35 45	2	,, ,,	35 32
Bd	310	,, ,,	39 37		39 2 – 39 56	20	,, ,,	39 35
	830	,, ,,	42 34		42 27 – 42 41	2	,, ,,	42 55½
Bx	520	,, ,,	44 31		43 42 – 45 0	8	,, ,,	44 42½
	13.6.0	,, ,,	48 58			1	,, ,,	48 51
Bc	210	,, ,,	51 7		50 52 – 51 29	30	,, ,,	51 7
	11.7.0	,, ,,	57 44		57 30 – 57 58	2	,, ,,	57 38
	760	,, ,,	64 45			1	,, ,,	64 48½
Bb	110	,, ,,	68 3		67 15 – 68 32	28	,, ,,	68 2½
	570	,, ,,	74 8			1	,, ,,	73 56
	580	,, ,,	75 43		75 31 – 75 56	3	,, ,,	75 51
Bz	120	,, ,,	78 44		78 25 – 79 19	11	,, ,,	78 36
Ba	010	,, ,,	90 0		89 39	8	,, ,,	90 0

IV. The Lattice Arrangements.

The advantages of the use of the gnomonic form of projection in the determination of the zonal properties of a crystal is well known. Owing to the fact that all great circles on the sphere, and therefore zones on the crystal, appear as straight lines on the projection, it follows that, if the projection be made on a plane perpendicular to the axis of some zone—usually the, or one of the, principal zones of symmetry on the crystal—all the zones passing through a pole in this zone are projected as straight lines intersecting one another at infinity, or, in other words, as parallel straight lines. In the case, therefore, of a simple crystal of the usual kind a gnomonic projection prepared in the foregoing manner takes the form of a continuous network, the nodes of which represent the principal observed faces. If, however, we prepare a gnomonic

projection of sartorite on a plane perpendicular to the edge of the prism-zone (fig. 10), we see at once that we obtain a patchy network which

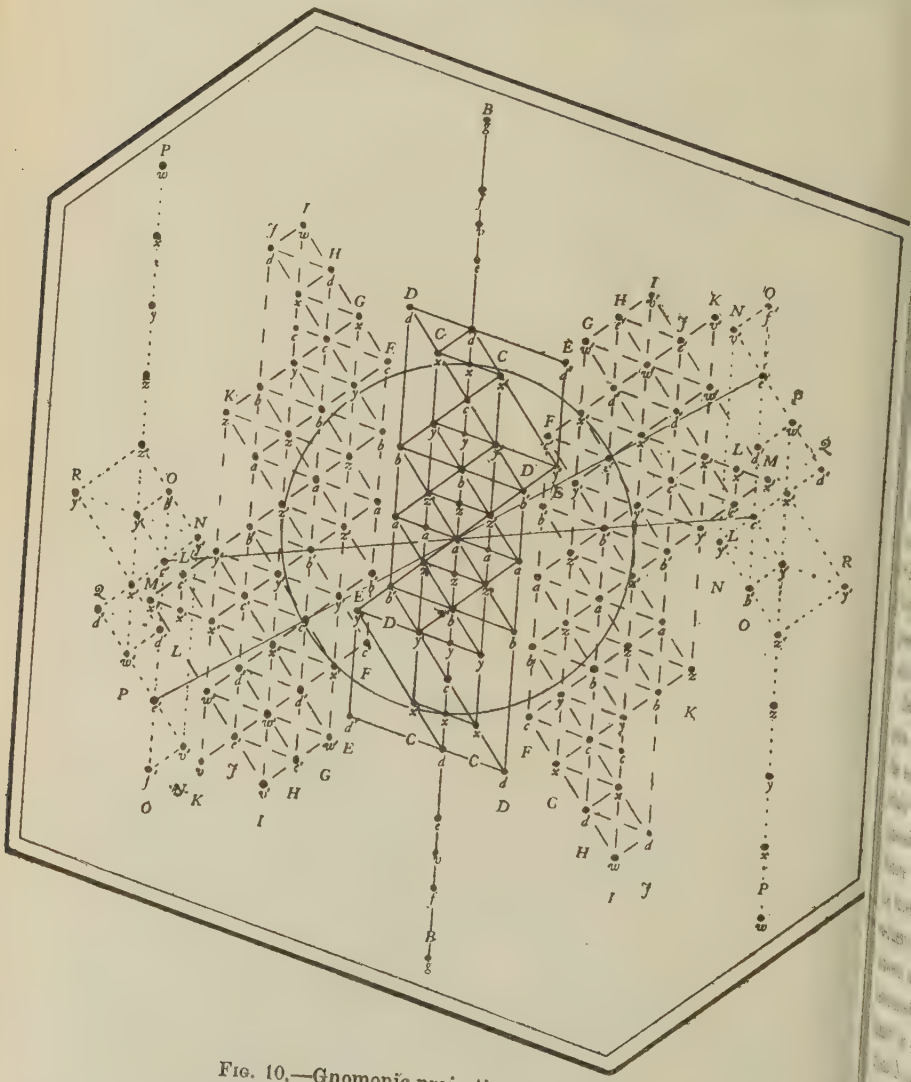

FIG. 10.—Gnomonic projection of sartorite.

is not continuous over the whole of the projection. A brief study of the projection shows that the discontinuity cannot be set down as due to

twinning or repeated twinning about (100), which is the ordinary twin-plane, or about any other face or axis. Zones passing through the pole (100) are continuous right across the diagram, and are, indeed, individually quite normal. It is, however, otherwise with zones passing through other poles in the prism-zone. The spacing in all straight lines parallel to a particular direction remains the same—that is to say, the linear distances between the points representing crystal-faces are simple multiples of the same unit; but these straight lines, if extended over the diagram, do not in general cross at nodal points the series of parallel straight lines representing the zones radiating from the pole (100).

There are in fact five different networks corresponding to as many lattices. Lattice I, which includes the, if present, usually conspicuous dome-zone, is monoclinic in symmetry. Close to it on either side of the vertical straight line (in the position of the drawing) which corresponds to the dome-zone lie a pair of similar networks, which are related to one another by twinning about the axis of symmetry; this lattice II is triclinic in symmetry. Farther away from the central straight line, and close to the sides of the diagram, we find another pair of similarly related networks; this lattice III is likewise triclinic in symmetry. Lattice III is far less conspicuous than lattice II, crystal No. 1 alone possessing many faces belonging to the former; but, strange to say, the unit pyramidal form selected by vom Rath belongs to lattice III.

Besides the identity of spacing in parallel straight lines on the diagram to which we have already alluded, there is another relation between the several lattices. If we extend the networks until they overlap, we obtain for the five crystals whose cross-zonal relations we were able to determine, the lattice arrangements depicted in fig. 11. The underlying feature of all of them, despite certain noticeable differences, is that the three adjacent nodes, each belonging to a different network, are co-linear, and the node belonging to lattice II bisects the distance between the nodes belonging to lattices I and III. This property was determined from the observations made on crystal No. 1, and was confirmed by observations made on its companion crystal No. 2 and on crystal No. 5; the three crystals Nos. 3, 4, and 6 were entirely lacking in faces of lattice III. From this property it follows, as is shown on the gnomonic projection (fig. 10), that the faces *Hb'* and *Oc'*, belonging to lattices II and III, lie in a zone with *Ba* and therefore with the same faces *Hb'* and *Oc'* belonging to the companion lattices. The diagrams in fig. 11 show that crystals Nos. 1 and 5 are of the one, and crystals

Nos. 3, 4, and 6 are of the other kind, a distinction indicative of the end of the crystal represented; none of the crystals is double-ended. but, as has been mentioned, Nos. 1 and 2 were at one time opposite ends of a single crystal.

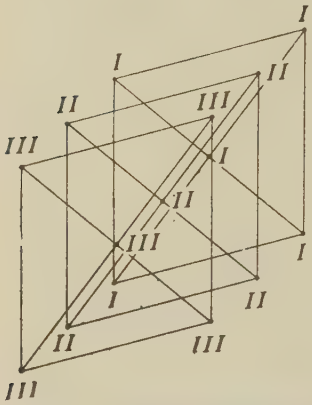

Fig. 11 a.—Lattice of crystal No. 6 (p. 298). [The lattice of crystal No. 3 is practically identical with this.]

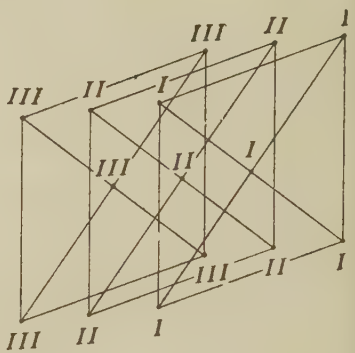

Fig. 11 b.—Lattice of Crystal No. 4 (p. 289).

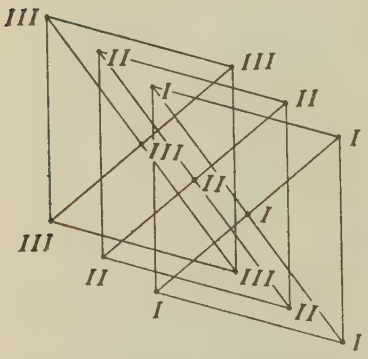

Fig. 11 c.—Lattice of crystal No. 1 (p. 274).

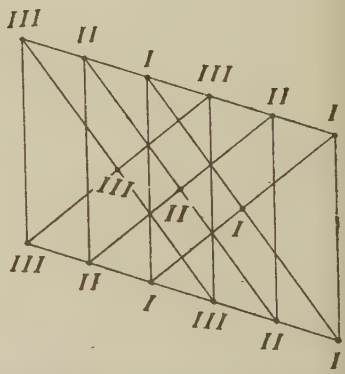

Fig. 11 d.—Lattice of crystal No. 5 (p. 293).

It may fairly be asked—do the differences in the arrangements shown in fig. 11 as characterizing the five crystals really exist, or may they not be due to errors of observation? We have admitted that the determination of the origin of measurements as the intersection of zones is necessarily liable to error when the reflections used for the purpose

re neither very bright nor very distinct, and further that the faces elonging to lattices II and III, especially the latter, often afford faint nd nebulous reflections, the concordance between the observed and the omputed values of the co-ordinate angles being, as may be seen from ne tables above, far from exact. Were it not for actual tests of the onal characters made on the three-circle goniometer—one of the great dvantages of this type of goniometer—we should have hesitated to elieve in the reality of the differences in the lattice arrangements, even have overlooked them altogether. In the case of crystal No. 6, hich was the first one to be measured on the three-circle goniometer, e zonality with respect to the pole (101) between faces belonging to ifferent lattices is so close that any slight divergence might readily e attributed to the small departures from the theoretical positions hich are common in the faces of all crystals. In the case of crystal o. 5, which was the next one measured on that instrument, on the ontrary, while there was almost perfect zonality with respect to the ole (001), there was none with respect to (101), as in the previous stance. No further light was thrown on the problem until crystal o. 1 was investigated, when it was clear that in this case there was o zonality with respect to either of the poles mentioned, or, indeed, to ny other pole in the prism-zone except (100). The want of zonality as not large in the case of the pole (101); but even in this instance was found impossible to adjust the crystal in such a way that the flections given by the faces of different lattices crossed the field of e telescope of the goniometer along the horizontal wire on rotation of e crystal about the axis of the first circle. Crystal No. 3 is very milar to crystal No. 6, while the want of zonality in crystal No. 4 is en more marked than in crystal No. 1, but the arrangement is less rtain owing to the inferior development of this crystal. It is, of urse, precisely to this want of zonality in the cross-zones that the normal character of the indices given by Baumhauer for the faces served by him is due (cf. p. 266).

It may be noticed from the gnomonic projection (fig. 10) that the veral networks overlap but slightly. Further, a reference to the awings of the crystals, especially fig. 4, shows that the faces are ranged with respect to one another exactly according to the positions the poles corresponding to them, and that all the interfacial angles e salient, except possibly the angles between contiguous faces of fferent individuals of the same twinned crystal, a phenomenon that is no way connected with the problem under consideration. In the

following table we have tabulated the amount and direction of the shear which defines the transition of one lattice to that adjacent to it, the amount and the azimuthal angle being measured from the pole of monoclinic symmetry and from the plane at right angles to the common edge of the faces in the dome-zone respectively.

Table XI. Amount and direction of the inter-lattice shear.

Crystal.	Amount.	Azimuth.
No. 1 (fig. 11 c) ...	7°29′ ...	57°27′
No. 3 (cf. fig. 11 a)...	6 21 ...	43 47
No. 4 (fig. 11 b) ...	8 15 ...	83 54
No. 5 (fig. 11 d) ...	7 11 ...	72 0
No. 6 (fig. 11 a) ...	7 14 ...	45 33

The amount of the shear is constant for three of the crystals in spite of considerable variation in the azimuthal angle; it lies about a degree (57′) above or below this mean value in the case of the remaining two crystals, but this deviation may partly at least be explainable by error of observation. Evidently the azimuthal angle may vary considerably and to this variation is due the difference in zonal characters of the crystals to which we have drawn attention above.

For a plausible solution of the problem presented by the morphological characters of sartorite we may look to the changed physical conditions in which the crystals now find themselves. Undoubtedly they were formed at very much higher than ordinary pressures and temperatures. That many of the crystals are still in a state of strain is shown by their extreme brittleness; it is by no means uncommon for one spontaneously to break in two with an audible report. In the case of a well-developed crystal such as No. 1 we find five distinct sections running vertically from front to back in the position of the drawing (fig. 4). The central layer has apparently suffered no deformation. In the adjoining sections on either side the vertical layers of atoms appear to have successively slipped downwards in such a way that planes which were horizontal became inclined thereto at an angle of 7° 18′ (the mean value). On the outside of the crystal, right and left, we find another pair of sections, in which a similar amount of slipping of the vertical layers of atoms has occurred with respect to the positions of the atoms in the adjoining sections. The rigidity of sartorite is therefore relatively weak in certain directions. From the variability of the azimuthal angle of the shear we may argue that slipping of the atoms has taken place parallel to two different planes in relatively varying amounts. Since

there is a cleavage parallel to (100), the simplest explanation is to suppose that slipping of the kind in question has occurred parallel to that plane both in a downward direction, i.e. parallel to the axis of symmetry, and at right angles thereto, the relative amount of slip being probably constant vertically, but variable in the other direction. It will be noticed that the variability in shear is accompanied by a perceptible difference in the constants defining the constituent lattices of the several crystals. We have, in fact, in sartorite a deformation similar to that long known in the case of crystals showing the so-called optical anomalies; but in this instance, as also in the case of calaverite, it is so comparatively large as to be measurable on a goniometer.

The extremely striated character of the prism-zone and the variability from crystal to crystal of the observed angles in this zone is suggestive not only of the oscillatory effect of repeated twinning about (100), which undoubtedly often occurs, but also of some interruption of the homogeneity of the internal structure. In a many-faced zone on a normal crystal we find the whole gamut of simple indices represented, but such is not the case with sartorite, as a reference to the tables of measured angles will show; not only are many simple ratios not found, but, in order to obtain even fair approximation with the observed angles, it was necessary to select unusual indices. It is possible that certain of the prism-faces are determined as the intersection with zones connecting faces each of which belongs to a different lattice. Thus the zone *Ba Hb′ Oc′* intersects the prism-zone in a face which subtends with (100) an angle of 81° 28′ calculated on the data for crystal No. 1. A reflection giving an angle of about this amount has not infrequently been observed. A few further points connected with the crystalline development are worth noting. The angle subtended between the poles (101) and (10$\bar{1}$) is in all cases very nearly a right angle, the following respectively being the values determined for the crystals Nos. 1, 3, 4, 5, and 6:—86° 44′, 89° 29′, 86° 32′, 86° 58′, and 87° 42′. Other angles of nearly a right angle are met with. For instance, the distance angle of the face *Py′* differs only a few minutes of arc from a right angle, the observed value in the case of crystal No. 1 being 89° 52′. The distance angles for two other faces approximate to a right angle, although not so closely as in the previous instance. Thus we have for *Jb′* on crystal No. 1 89° 4′, 89° 11′, 89° 15′, crystal No. 4 89° 53′, crystal No. 5 89° 13′, and crystal No. 6 89° 7′: and for *Gz′* on crystal No. 1 88° 30′, crystal No. 4 89° 50′, crystal No. 5 89° 35′, and crystal No. 6 88° 36′.

V. Sartorite-α.

The two crystals (B.M. 1917, 390) which were numbered by Trechmann 1 and 2 and formed the principal subject of his memoir were measured on the three-circle goniometer with the view of ascertaining whether any way of bringing them into crystallographical harmony with the ordinary sartorite of vom Rath would suggest itself, but without success; although the angles in the dome-zones were almost identical with those found for sartorite, the dissimilarity in the case of any other zone can only mean that these two crystals belong to a different, though no doubt closely related, species, which for distinction we have named sartorite-α. Besides the close relation in the dome-zone there is a certain similarity in the azimuthal angles at (100), as may be seen in the following table, in which we compare the calculated values for sartorite-α with those given in Table IV for crystal No. 1 (p. 278).

Table XII. Azimuths of zones passing through (100).

Zone with	Sartorite.	Zone with	Sartorite-α.
I 021	79°33′	041	78°11′
,, 001	69 45½	021	67 17½
II 012	49 42	011	50 4½
,, 025	44 5	045	43 42
,, 013	39 25	023	38 32

The additional facilities provided in the form of goniometer used enabled us to note a few faces not recorded by Trechmann; the measurements determining them are given below. The calculated values are based on the data recorded by him.

Table XIII. Additional faces of Trechmann's Crystals Nos. 1 *and* 2 (*Sartorite-α*).

Crystal.	Face.	Refl.	Observed.		Calculated.	
			ϕ	ρ	ϕ	ρ
1	344	b	50° 8′	58° 27′	50° 4½′	58° 54′
,,	$\bar{1}33$	b	,, ,,	86 0	,, ,,	86 23½′
2	704	b	0 0	34 47	0 0	34 23′
,,	503	b	,, ,,	35 45	,, ,,	35 54
,,	304	b	,, ,,	63 2	,, ,,	63 19
,,	305	b	,, ,,	70 15	,, ,,	70 15½
,,	645	b	43 45	55 45	43 42	56 7½′
,,	245	b	43 41	66 49	,, ,,	66 24′

In addition to these two crystals, a tiny crystal (B.M. 1917, 401) of rtorite, measuring only 1 by 0·5 by 0·2 mm., was met with on one of echmann's specimens and the measurements given in Table XIV were ade on it. The forms (140) and (8.12.3), the latter being somewhat ubtful, are new. The crystal showed also faces at the other end, but fortunately it fell off the wax of the crystal-holder and was lost before t end was measured.

ble XIV. Observed and calculated values of the co-ordinate angles from (100) of Crystal No. 7 (Sartorite-a).

Face.	Refl.	Observed.		Calculated.	
		ϕ	ρ	ϕ	ρ
$40\bar{1}$	g	0° 0′	14° 41′	0° 0′	15° 27′
$20\bar{1}$	f	,, ,,	29 34	,, ,,	30 28
$40\bar{3}$	b	,, ,,	42 26	,, ,,	43 17
$10\bar{1}$	b	,, ,,	52 31	,, ,,	53 25
$70\bar{8}$	b	,, ,,	58 20	,, ,,	58 6
$90\bar{1}$	b	,, ,,	6 54	,, ,,	6 47
$40\bar{1}$	f	,, ,,	15 10	,, ,,	15 27
$80\bar{3}$	b	,, ,,	22 47	,, ,,	23 9
$20\bar{1}$	b	,, ,,	29 58	,, ,,	30 28
$40\bar{3}$	f	,, ,,	43 5	,, ,,	43 17
$10\bar{1}$	f	,, ,,	52 42	,, ,,	53 25
$40\bar{1}$	b	,, ,,	14 25	,, ,,	15 27
$50\bar{2}$	b	,, ,,	25 17	,, ,,	24 39
$70\bar{4}$	f	,, ,,	34 11	,, ,,	34 23
$30\bar{2}$	b	,, ,,	40 40	,, ,,	39 18½
$40\bar{3}$	b	,, ,,	43 36	,, ,,	43 17
001	b	,, ,,	77 56	,, ,,	77 48
$40\bar{1}$	b	,, ,,	15 31	,, ,,	15 27
$70\bar{3}$	b	,, ,,	25 59	,, ,,	26 20
$70\bar{4}$	g	,, ,,	34 27	,, ,,	34 23
$70\bar{5}$	b	,, ,,	41 41	,, ,,	41 37
221	b	67 12	50 32	66 50	50 28
$\bar{1}21$	f	67 33	73 56	,, ,,	74 7
$\bar{2}41$	f	78 8	70 41	78 11	70 51
041	b	,, ,,	86 29	,, ,,	87 24
441	b	78 15	50 24	,, ,,	50 17½
241	f	,, ,,	66 20	,, ,,	66 21
041	b	,, ,,	87 19	,, ,,	87 24
441	f	78 19	50 18	,, ,,	50 17½
8.12.8	b	,, ,,	64 16	,, ,,	64 27
241	g	,, ,,	70 45	,, ,,	70 51
041	b	,, ,,	87 40	,, ,,	87 24
410	b	89 53	18 30	90 0	17 19
210	b	,, ,,	31 55	,, ,,	31 56
320	g	,, ,,	39 44	,, ,,	39 44
430	b	,, ,,	43 39	,, ,,	43 5
110	g	,, ,,	51 17	,, ,,	51 16
120	f	,, ,,	68 14	,, ,,	68 9
140	g	,, ,,	78 44	,, ,,	78 40
320	b	89 56	39 31	,, ,,	39 44
110	f	,, ,,	51 10	,, ,,	51 16
120	f	,, ,,	68 2	,, ,,	68 9

Although no attempt to determine the chemical composition sartorite-α has been possible, it is not a very hazardous conjecture suppose that in this respect both species, sartorite and sartorite- are alike, the relation between them resembling that between calaveri and krennerite. In the case of the latter pair, it will be remembere the chemical composition is the same, but the crystalline form ve different, although certain angles are very similar;[1] krennerite is norm in its crystallization, but calaverite shows the same type of arrangeme of lattices as we have found in sartorite.

VI. Doubtful Crystals without pyramidal faces.

Since the prism-zone of sartorite-α is little striated and the reflectio yielded by it correspond to the positions required for poles with norm simple indices, it is probable that the remaining measured crystals whi showed dome-, but not pyramidal, faces are, because of the striated nature the prism-zone and the uncertainty of the readings afforded by it, sartori and not sartorite-α. To illustrate the variable nature of the measur ments in the prism-zone, we may take two well-formed crystals, 8 and (B.M. 1918, 408 (2), and B.M. 1918, 408 (9)), which are numbere respectively 2 and 9 in Solly's collection, the former (fig. 1, p. 27 measuring about 6 mm. and the latter 15 mm. in length. It will seen from the table below that whereas the agreement in the dome-zo is close, very few, if any, of the angles in the prism-zone appear correspond. The angles in every case have been measured from (10 and the calculated angles are based on the data found for crystal No. 1

[1] See Mineralogical Magazine, 1902, vol. xiii, p. 142.

Table XV. Measurements made on Crystals Nos. 8 *and* 9.

Crystal No. 8.

ace.	Refl.	Observed.	Calculated.
10	g	39°24′	39°35′
10	g	51 6	51 7
10	g	68 2	68 2½
30	b	82 20	82 21
10	b	90 0	90 0
10	g	50 58	51 7
10	g	67 55	68 2½
20	b	78 53	78 36
04	b	24 56	24 32
01	s	34 39	36 6
02	s	38 9	36 17
07	b	53 9	53 15½
01	s	51 10	50 48
03	s	57 26	57 17
09	b	72 25	71 45½
01	s	36 40	36 6
01	s	48 15	50 48
05	s	80 30	80 56
01	f	21 43	22 5
04	f	24 47	24 32
05	f	26 25	26 15
03	b	29 45	29 57
11	f	37 30	36 6
04	b	42 14	42 20
33	b	44 21	44 48
77	s	53 21	53 15½
11	b	74 41	74 28
55	b	81 26	80 56

Crystal No. 9.

Face.	Refl.	Observed.	Calculated.
310	g	39°33′	39°35′
520	f	44 15	44 42½
210	f	50 45	51 7
	f	51 15	
110	b	67 53	68 2½
210	b	51 18	51 7
110	g	67 59	68 2½
509	s	48 42	48 29
405	b	58 30	59 10
301	b	15 25	15 42
509	s	48 10	48 29
10$\bar{1}$	b	51 45	50 48
405	b	59 10	59 10
105	b	63 36	63 35½
702	b	15 20	15 44
503	f	32 49	32 55
705	b	37 57	38 35½
405	f	40 41	40 57
10$\bar{1}$	f	50 24	50 48
13.0.1	b	3 59	3 57
601	b	8 28	8 19
301	b	16 5	15 42
102	s	49 56	50 29½

he striations on the face *Bb* (110) of crystal 8 (fig. 1) are parallel ectively to the edges with (001) and (403). The bracketed angles he column of observed angles correspond to the ends of a nearly nuous band of reflections.

VII. Summary.

s the result of the investigation forming the subject of this paper the wing conclusions have been drawn :—

The six crystals, the measurements of which are given in complete ll above, belong to the same species (sartorite) as that described by Rath and Baumhauer. The faces observed on the ends of the als are referable to three distinct and non-congruent lattices, of n one is monoclinic and the other two are triclinic in symmetry.

The latter two are, however, twinned about the axis of symmetry s that in the case of a fully-developed crystal there are altogether fiv distinct lattices. The shear by means of which each lattice may b imagined to be transformed into the one adjoining it is constant i amount, but variable in direction. At the same time there is a pe ceptible difference in the constants defining the constituent lattices the several lattices.

2. The two crystals figured and described by C. O. Trechmann together with a third described in this paper, belong to a distinc though no doubt closely allied, species, which for convenience we hav named sartorite-α.

3. Sartorite and sartorite-α have probably the same chemical com position, and the relation between their morphological characters parallel to that existing in the case of calaverite and krennerite.

On the use of the gnomonic projection in the calculation of crystals.

By G. F. Herbert Smith, M.A., D.Sc., F.G.S.

Assistant in the Mineral Department of the British Museum.[1]

[Read January 15, 1918.]

CONSIDERED from the crystallographical point of view the outstanding feature of the gnomonic projection is the fact that all great circles on the sphere, and consequently all zones on the crystal, appear on the diagram as straight lines. In order to secure its full advantages, it is necessary to take the plane of the paper at right angles to the axis of a zone, and preferably one of the principal zones of symmetry on the crystal. In such an arrangement the points on the diagram corresponding to the poles in the zone mentioned—which for convenience in reference to the diagram we may term the equatorial zone—all lie at infinity, and therefore, if the straight lines representing the zones passing through the principal poles of symmetry in the equatorial zone are drawn, the diagram takes the form of a network consisting of parallelograms (fig. 1), which in particular cases become rectangles, or even squares. Except in the monoclinic system when the pole of symmetry lies in the equatorial zone, and always in the triclinic system, the pole of the projection O coincides with a node of the network.

The linear distance separating the nodes lying on any one straight line on the diagram are very simply related to the indices of the corresponding faces. In fig. 1, for instance, we have a series of parallel straight lines, $P_1P_2P_3$, $Q_1Q_2Q_3$, $R_1R_2R_3$, representing zones passing through a pole A lying in the equatorial zone. The straight line $Opqr$ is drawn through the pole of projection at right angles to the series intersecting them successively as shown. Suppose the angular distances

[1] Published by permission of the Trustees of the British Museum.

of the poles corresponding to $P_1P_2P_3$ measured from the pole A are ρ_1, ρ_2, ρ_3 respectively, and the azimuthal angle of the zone measured from the equatorial zone is ϕ, then, if a be the radius of the sphere of projection, we have $Op = a \cot \phi$, $pP_1 = a \cot \rho_1 . \operatorname{cosec} \phi$, and similarly for P_2 and P_3, whence it follows that

$$\frac{P_1P_3}{P_1P_2} = \frac{pP_3 - pP_1}{pP_2 - pP_1} = \frac{\cot \rho_3 - \cot \rho_1}{\cot \rho_2 - \cot \rho_1},$$

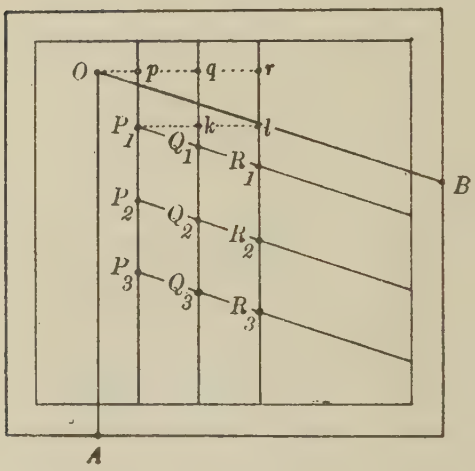

Fig. 1.—Gnomonic projection.

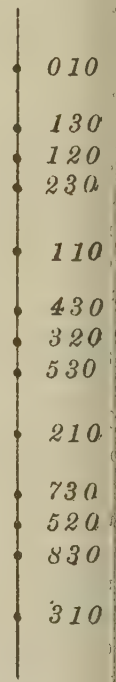

Fig. 2.—Zone in gnomonic projection.

which is equal to the ordinary anharmonic ratio subsisting between the indices of the corresponding faces. Suppose now that P_1 is (010), P_2 (110) (fig. 2), then (210) is just twice as far from (010) as (110) is, and (310) three times, and so on. Similarly, to find the point corresponding to (120), we bisect the unit (010) : (110), and that corresponding to (130), we take a third of the distance, and so on.

In the modern method of measuring crystals the position of a pole is determined by means of bi-angular co-ordinates—generally its distance

measured from a fixed pole called the origin, and its azimuth measured from a fixed plane passing through the latter. To make the fullest use of the zonal properties of crystals, we must take as origin a pole corresponding to a face or at least a possible face on the crystal, and preferably one of symmetry. If the origin lies in the equatorial plane and we prepare a gnomonic projection in the manner described above, we shall in the general case have a diagram similar to the one shown in fig. 1. Suppose A be the origin, then the linear co-ordinates of P_1 on the diagram are given by $Op = a \cot \phi$; $pP_1 = a \cot \rho_1 \cdot \operatorname{cosec} \phi$. The radius of the sphere of projection a should be taken as 10 cm., or similar simple unit.

The first of the co-ordinates given above, which depends on the azimuth only, is readily found, because the unit distance pq and the linear co-ordinate of one of the points p, q, r are two of the factors which are either taken direct from the observations or easily calculated from them, using a table of natural cotangents. When we know the co-ordinate of such a point as p we at once deduce that of any other by multiplying or dividing the unit distance by a simple number or a simple ratio. Any large error is easily guarded against if we measure the distances on the diagram. A reference to the table of cotangents gives us at once the corresponding angle.

The calculation of the angular distances presents greater difficulty, especially in the general case. If the pole of projection O corresponds to a possible face on the crystal it coincides with one of the nodes of the network, and many of the difficulties disappear; the unit distance, for instance P_1P_2, is either given directly by, or readily calculated from, the observations made in the zone passing through O and A. In the case of a triclinic crystal it might be necessary to calculate the co-ordinates of C (fig. 3 a), one of the principal poles. If the poles are determined as the intersection of zones[1]—a convenient way of working up a crystal for which a three-circle goniometer is very useful—then in the spherical triangle ABC (fig. 3 a) we know the side c and the angles A and B, and can compute in the ordinary way the other two sides, which are the distances of C from A and B, and the angle C. We have next to find the unit distance such as P_1P_2. If we use as data some of the azimuths at B, we know or can readily compute the length of Cm (fig. 3 b), and we have $Ce = Cm \operatorname{cosec} c$, the angle at the point C in the diagram being equal to the side c in the equatorial zone. Once we know one of the nodes such as P_1 in a straight line, and

[1] See Mineralogical Magazine, 1902, vol. xiii, p. 126.

the unit distance in the series of straight lines to which the latte belongs, as before we find the co-ordinates of the other nodes b adding or subtracting simple proportion of the unit, and can check the accuracy of the computation by direct measurements on the diagram To obtain the corresponding angular values, we have to multiply th linear co-ordinates by $\sin \phi$, and look up in the tables the angle corresponding to the cotangents thus found. If the diagram consist of rectangles, we have from zone to zone the same linear co-ordinate in the several straight lines, and have only to multiply by the sin of a different azimuthal angle. In the general case, however, to pas from a pole such as P_1 to another such as Q_1 we shall have to ad or subtract a simple proportion of kQ, which is equal to pq cot c.

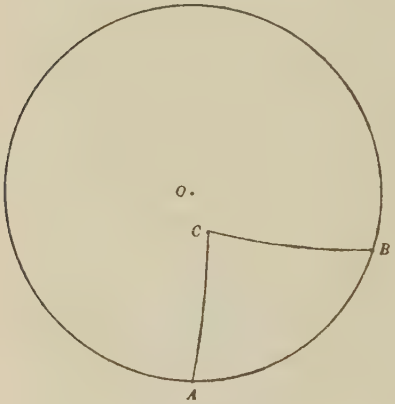

Fig. 3 a.

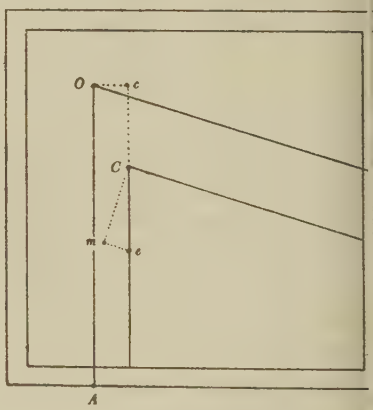

Fig. 3 b.

Stereographic and gnomonic projections of a triclinic crystal.

This method was devised to facilitate the lengthy calculations require in the case of sartorite.[1]

The only serious objection to the use of the gnomonic projectio in the general discussion of the morphological characters of crystal is that from its nature it is impossible to show on it the point representing the faces whose normals are parallel to the plane the projection, or in fact to show on a diagram of reasonable size th points representing faces whose normals are inclined to the perpen dicular to the plane of the projection at angles greater than 65°. I practice the objection is not of much moment, because few faces o a crystal, with the exception of those in the equatorial zone, are s

[1] This vol., p. 259.

steeply inclined that their poles lie beyond the limit mentioned, and the equatorial zone may be depicted in the usual way on the outer edge of the diagram. Nevertheless, for some purposes it is convenient to view the whole of the poles representing the faces on a crystal, and we may accomplish this by projecting on to the faces of a cube touching the sphere of projection at, if possible, the principal poles of symmetry.

Now, when a straight line representing a zone crosses the boundary on the diagram separating the two planes of projection, its direction is in general changed, but the new direction is readily found by graphical means in the following manner. Suppose A and B (fig. 4) are the oles

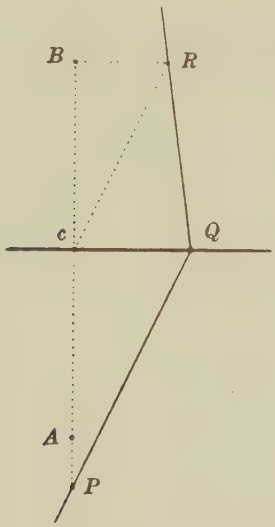

Fig. 4.

of projection on the two planes of projection. Join AB, and let it meet the boundary at c. Let PQ be some zonal line in the first plane, and let it meet AB, produced, if necessary, in P. If PQ be inclined to BA at an angle θ, the poles in which the corresponding zones intersect the equatorial zone, whose edge is perpendicular to this plane, subtend at the centre of the sphere the same angle θ. This equatorial zone appears on the second plane as a straight line through B parallel to the boundary between the two planes, and, if R is the second pole, we have $BR = a \tan \theta$, where a is the radius of the sphere. But Bc is a. Therefore the angle BcR is θ, and cR is parallel to PQ. Now R is a pole on the zone in question, and hence, if we join QR and prolong

it, we have on the second plane the straight line representing that zone. The rule, therefore, for finding the new direction is very simple. Draw through the point c a straight line parallel to the zonal line in the first diagram. The point in which it meets the straight line through B at right angles to Bc represents a pole on the zone. The straight line

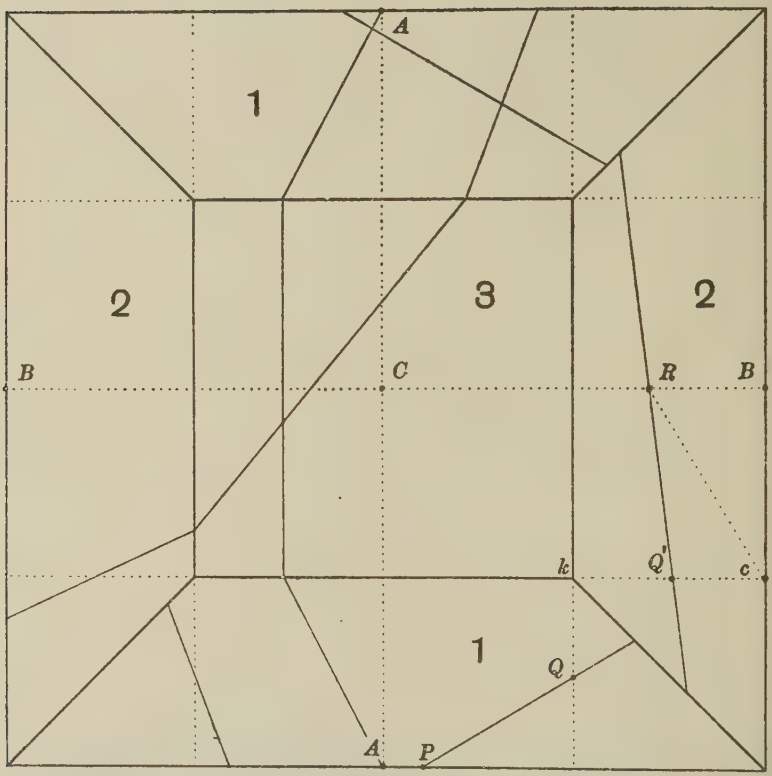

FIG. 5.—Composite gnomonic projection on five adjoining faces of a cube.

passing through this point and the point in which the zonal line in the first plane intersects the common boundary is the zonal line in the second plane.

Fig. 5 shows a composite gnomonic projection of the kind suggested. Suppose that the cube face 3 lies in the plane of the paper, and that the cube faces 1 and 2 are turned about their respective edges with 3 until they likewise lie in the plane of the paper. Since faces on the under

half of the crystal may be represented by the parallel faces on the upper half, the lower halves of the diagram drawn on the side faces 1 and 2 need not be included. The latter faces, after rotation into the plane of the paper, meet only at the respective corners, but the intervening gaps may conveniently be made use of for continuing the zonal lines up to the boundaries equally inclined to both squares in the manner depicted in the figure; this method may be very useful in the case of poles lying on one or other cube face near their common edge. Of course, the poles appearing in the triangles adjoining 2 appear also on the face 3, and *vice versa*. The procedure for finding the new direction of a zonal line crossing the boundary between the cube faces 1 and 2 is only slightly different from that given above. Let us consider the zonal line $PQQ'R$ in fig. 5; then $kQ = kQ'$, and cR is drawn at right angles to PQ. It will be noticed that zonal lines passing through the pole of projection on one of the cube faces, after crossing a boundary, traverse the next face in the direction at right angles to that boundary.

The possible axes of crystal-symmetry.

By John William Evans, LL.B., D.Sc., F.R.S.

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[Read March 20, 1917.]

THE following is a simple general proof that, on the hypothesis that crystals have a homogeneous cellular structure, the only possible axes of symmetry are those with cyclic numbers 2, 3, 4, or 6.

According to this hypothesis, every crystal is entirely made up of minute space-partitions or cells, which (apart from those of purely surface layers) have all the same form, size, internal configuration, orientation, and external relations. Accordingly, every point in one cell has an *equivalent* point exactly corresponding to it in every other cell. From the identity of external relations it follows that any two equivalent points form part of a rectilinear line or *row* of equivalent points at equal distances from one another, and that every such row is one of a series of parallel rows of identical character; also that any two intersecting rows of equivalent points lie in a plane or *net* of equivalent points arranged in parallel rows in different directions, and that such a net forms one of a series of parallel nets with identical characters.

If now the crystal possess an axis of simple or co-directional symmetry (see this volume, p. 238), there must be a local axis of symmetry with the same cyclic number, character, and orientation traversing, in exactly the same manner, every individual cell.[1] It follows that there must be a series of nets of equivalent points at right angles to an axis of symmetry; for, if any point in the crystal-structure be taken, there will be by virtue of every local axis of symmetry (except that one, if any, which traverses the point taken) one or more equivalent points lying in a plane which is at right angles to the axis of symmetry and contains the original point; and as there are an indefinite number of local axes of symmetry parallel to one another, there must be an indefinite number of equivalent points lying in the same plane at right angles to them.

Now consider any plane at right angles to an axis of symmetry. This will be met by the local axes of symmetry in equivalent points that

[1] This would include an axis traversing a plane forming part of the cell boundary.

form a net. Let O and P be two of such equivalent points on local axes of symmetry which adjoin each other on any row in that net—that is to say, which have no other intermediate equivalent point between them. Let their distance from one another be a.

Then since O is situated on a local axis of symmetry and OP is at right angles to it (see figs. 1–5), there will be another point Q equivalent to P at the same distance a from the point O in such a position that the angle $POQ = \frac{2\pi}{n}$, where n is the cyclic number of the axis of symmetry and therefore an integer; and it will not differ in orientation.

In the same manner, since the point P is on a local axis of symmetry, there will also be an equivalent point R, on the same side of OP as Q, such that $PR = OP$ or a, and the angle $OPR =$ the angle $POQ = \frac{2\pi}{n}$.

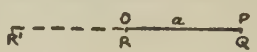
Then QR will form part of a row of equivalent points, and since it is parallel to OP, and Q and R are equivalent to O and P, the row QR must be in all respects identical with the row OP, and equivalent points must occur along it at the same intervals as along OP. Accordingly as O and P are adjoining points on OP and therefore at the minimum distance a, QR must be an integral multiple of OP, or a.

Through O draw OR' parallel to PR, meeting QR at R'. Then $QR = R'R + QR' = a + 2a \cos OQR$ (or OQR^1) $= a - 2a \cos POQ = a\left(1 - 2\cos\frac{2\pi}{n}\right)$. In order that this should be an exact multiple of a, $2\cos\frac{2\pi}{n}$ must be an integer, positive, negative, or zero; $\cos\frac{2\pi}{n}$ must therefore be either an integer or half an integer. As its limiting values are $+1$ and -1, its only possible values are $+1, +\frac{1}{2}, 0, -\frac{1}{2}$, and -1. The corresponding values of $\frac{2\pi}{n}$ and n are shown by the following table:

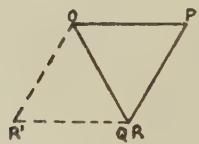
$QR = a\left(1 - 2\cos\frac{2\pi}{n}\right)$	$2\cos\frac{2\pi}{n}$	$\cos\frac{2\pi}{n}$	$\frac{2\pi}{n}$	n
$-a$	$+2$	$+1$	$\begin{cases} 2\pi \\ 0 \end{cases}$	1 *infinity*
0	$+1$	$+\frac{1}{2}$	$\frac{\pi}{3}$	6
$+a$	0	0	$\frac{\pi}{2}$	4
$+2a$	-1	$-\frac{1}{2}$	$\frac{2\pi}{3}$	3
$+3a$	-2	-1	π	2

The value $n = 1$ signifies that a rotation through a complete circle is necessary if coincidence is to occur, or, in other words, that the axis has no special symmetry. The value $n =$ infinity implies that the cells are infinitely numerous and therefore infinitely small.

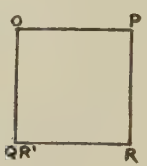
The corresponding diagrams are as follows :—

Fig. 1.— 

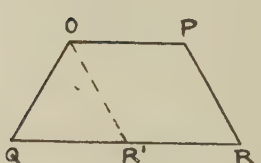
$QR = -a$; $n =$ infinity, or 1.

Fig. 2.— 

$QR = 0$; $n = 6$.

Fig. 3.— 

$QR = +a$; $n = 4$.

Fig. 4.— 

$QR = +2a$; $n = 3$.

Fig. 5.—

$QR = +3a$; $n = 2$.

Figs. 1–5. Possible axes of crystal-symmetry.

In the case of contra-directional symmetry—in which a rotation of $\frac{2\pi}{n}$ results not in coincidence but in a reversal of uniterminal directions—similar considerations hold. The points Q and R will either be exactly equivalent to O and P or differ from them only in the orientation of their relations. In either case QR must be an integral multiple of OP and the proof already given applies.

Story-Maskelyne deduced from the law of rationality of indices the condition that $2\cos\frac{2\pi}{n}$ is rational, and then proved that, if n is an integer, the only rational values of $2\cos\frac{2\pi}{n}$ are integers (W. J. Lewis, Crystallography, 1899, p. 119).

On the origin of septarian structure.

(With Plate XI.)

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[Read June 18, 1918.]

I. *Historical.*

In the *Geological Magazine* for 1913 there appeared three papers discussing the origin of the system of cracks in septarian nodules. Dr. A. Morley Davies[1] opened the discussion in a paper where, after a summary of earlier literature, he again put forward an older idea. Without adducing evidence, he considered:

(*a*) that interposition of particles between those of the original matrix caused expansion which set up tensile strain in the growing body;

(*b*) that the cracking of the nodule was due to the relief of those tensile stresses.

J. E. Todd[2] followed, supporting the 'expansion' theory and adducing some evidence in favour of it. Later, T. Crook,[3] upholding the more popular 'contraction' theory, replied to both papers and to some extent disposed of Todd's evidence. He specified, however, that he considered the structure to be due to the shrinkage *on* a solid external shell as the cause, rather than contraction of the whole concretion towards the centre.

On reading these papers it seemed to me that the subject was not sufficiently investigated, and the results of work consequently undertaken are presented below.

II. *The Septarian Structure.*

Septarian structure is commonly stated to consist of radiating cracks uniformly widening towards the centre, with a series of concentric

[1] A. M. Davies, Geol. Mag., 1913, dec. 5, vol. x, pp. 99–101.
[2] J. E. Todd, ibid., pp. 361–364.
[3] T. Crook, ibid., pp. 514–515.

cracks usually added. This combination would produce a spider-web appearance. This description is, however, inaccurate and misleading. Except at the margin, the 'radial' system is rarely radial, being more usually quite irregular, and the width does not increase uniformly towards the centre; whilst the 'concentric' series, where it can be detected at all, is more irregular still.

On the other hand, a typical septarian nodule such as Plate XI, fig. 1 (kindly lent me by Mr. H. C. Sargent), shows the following structures:

(1) The bulk of the interior is divided up into irregular polygons[1] the sides of which could only be classified into the above two systems very roughly and inexactly. In three dimensions they really correspond to columns of polygonal section which run vertically through the nodule. In some cases the columns are snapped across in the centre; and, when the spaces are filled, the interior of such a nodule then appears to be a mass of calcite. (The large nodule from the Oxford clay in one of the Palaeontological galleries of the British Museum is an example.)

(2) The width of the cracks except in the immediate neighbourhood of the outside boundary is independent of their position in the nodule.

(3) The cracks in the marginal region are radial or rather normal to the boundary. They increase in width for a short distance inwards until they pass between the polygons, but become very fine and die off towards the margin, rarely penetrating to the outside.

(4) Within the nodule there is also a very distinct line (marked *a* in the figure), concentric with the boundary and from a tenth of an inch to several inches within it. This line marks the outward limit beyond which the septarian cracking does not usually extend.

Now, instead of simulating a spider-web, it will be seen that this structure reproduces the appearance of a film of clay allowed to dry, i.e. mud-crack structure (Plate XI, fig. 3).[2] The remarkable resemblance of the cracking system to septarian structure will at once be noticed.

However, there are occasional occurrences where the cracks form a truly radial system, and I have seen examples with a distinct concentric crack (Plate XI, fig. 2). But I do not find a simple relation between the size of the nodule and the system of cracks developed, as Todd claims in the article referred to above. At Bracebridge, Lin-

[1] A. Geikie (Text-book of Geology, 1903, 4th ed., p. 136) alone describes the cracking as polygonal.

[2] A similar figure of cracks in a dried clay film is given by S. Meunier, La Géologie expérimentale, Paris, 1899, p. 219, fig. 36.

olnshire, the smaller nodules had the typical structure. Moreover, the Museum collections that I have examined do not support Todd's conten- tion. The system developed depends upon a number of factors, among which size is probably included.

III. *Cracks in Timber.*

Timber, particularly when dried or 'seasoned', often develops charac- eristic systems of cracks which depend upon the nature of the decay that as set in, and the particular kind of tree in question. There are three ain types of cracks or 'shakes'.[1]

1. '*Heart Shake*' (fig. 1 *a*).—Cracks converge to the centre and increase n width uniformly towards the centre. This shake is due to incipient ecay in the heart, and consequently more rapid drying takes place here. The shrinkage is chiefly circumferential.

2. '*Star Shake*' (fig. 1 *b*).—Radial system of cracks which increase in

Fig. 1.—Cracks in timber.

a. 'Heart Shake.' *b*. 'Star Shake.' *c*. 'Cup Shake.' *d*. Shakes *a* and *c* combined.

idth outwards; due to the decay and more rapid drying of the outside. he shrinkage is again mainly circumferential, but in this case attains s maximum at the outside surface.

3. '*Cup Shake*' (fig. 1 *c*).—Concentric cracks due to the decay and ying of the inside and its shrinkage towards the centre.

Therefore, in timber, radial and concentric cracks of the types that ncern us are produced by the contraction, not expansion, of the inside. is also interesting to note that when heart and cup shakes are com- ned (fig. 1 *d*) they produce the spider-web, but not the mud-crack ructure.

IV. *Experiments with Clay Balls and Pats.*

In order further to test the type of crack produced by expansion and ntraction, I made some balls of wet modelling clay about $2\frac{1}{2}$ inches in

[1] T. Laslett and H. M. Ward, Timber, 1894, pp. 54–58.

diameter, and surrounded them by a portland cement mixture to act as an indicator of the inside movements. The following observations were made:

Set 1.—Balls dried in air. No cracks at all appeared on the outside. On cutting through, the inside was found to have shrunk away from the outside, leaving a concentric gap. In some cases, where such a break was only partial, an irregular crack or so ran through the body of the clay, very crudely imitating septarian structure.

Set 2.—Similar balls immersed in water. The expansion of the clay inside cracked the outer cement coat, the cracks forming a polygonal system. No cracks of any kind, and no separation of the layers, appeared on cutting through.

Set 3.—Similar balls soaked in concentrated brine. In this case no cracks appeared *outside*, but inside there was a distinct concentric crack partially separating the inner from the outer shell. There was, therefore, *no expansion of the clay, but actual contraction.*

In order to obtain further confirmation of these important results under conditions more favourable for observation, pats of very wet Reading clay were placed on glass squares.

Set 1.—Air dried. The usual polygonal system and desiccation cracks appeared wider at the free surface and diminished towards the glass boundary (Plate XI, fig. 3).

Set 2.—Immersed in distilled water. A cut made in the pat was partially filled up, but otherwise no change occurred.

Set 3.—Immersed in a concentrated solution of calcium chloride. After five minutes there appeared a polygonal series of fine desiccation cracks giving similar polygons to, but smaller in area than, those of Plate XI, fig. 3. After immersion for some days there is no doubt that the clay was slightly firmer and harder.

These experiments and the consideration of timber cracks tend to show:

1. That slight contraction of the inside *on* a solid outside shell combined with strong circumferential contraction would produce radial cracks widening inwards.

2. That expansion of the interior would produce radial cracks widening outwards.

3. That contraction *on* the inside would produce concentric cracks.

4. That either free or chemical desiccation is competent to produce a polygonal system of cracks.

V. *Composition of Septarian Nodules.*

Any contraction theory assumes that the interior of a septarian nodule has a more 'clayey' composition than the outside. Todd, in his papers,[1] states definitely, but without offering much in the way of evidence, that the nodules are of uniform composition throughout. As I was unable to find any investigation of the matter recorded, I made the following partial analyses.

Alumina and the other constituents present in considerable quantity were estimated. It may be remarked that owing to the difficulty of separating the finer calcite veining from the matrix, the values for lime inside a nodule probably come out much too high.

	No. I. Bracebridge.		No. II. Nottinghamshire.			No. III.
	Outside.	Centre.	Outside.	One inch from outside.	Centre.	Typical Clay, Bracebridge.
SiO_2 ...	24·7	13·1	12·3	8·0	4·5	53·1
Al_2O_3 ...	18·6	35·1	trace	2·0	4·0	31·1
Fe_2O_3 ...	34·3	4·7	7·2	3·9	3·5	7·3
CaO ...	—	22·9	36·3	45·3	46·0	—

I, Ironstone Septarium 6 inches diameter, Lower Lias, Bracebridge, Lincolnshire (Plate XI, fig. 2).

II, Limestone Septarium 9 inches diameter, Nottinghamshire (Plate XI, figs. 4, 5, 6).

III, Typical Lower Lias Clay, Bracebridge, Lincolnshire.

An inspection of the above table shows that there is an excess of alumina in the centre, and if alumina may be taken as an index of the 'clayey' matter, there is also an excess of this within the nodule. The veining of the cracks points to subsequent infiltration and no doubt there has been a certain amount of cementation by iron or lime. But whilst the composition of the nodule as found cannot be assumed to be the same as at the time of fracture, still such evidence as there is goes to show that a distinct difference in composition existed between the interior and exterior of a septarian nodule, sufficient to warrant the assumption of the contraction theory.

A comparison of the centre of the Bracebridge nodule with clay (anal. III) from the same pit shows that the former is not an inclusion of this clay. For example, a considerable part of the silica has been removed so that there is not sufficient left to saturate the alumina. The facts

[1] J. E. Todd, loc. cit.; also Bull. Geol. Soc. Amer., 1903, vol. xiv, pp. 353-368.

point to considerable chemical changes in the enclosed clay accompanying the formation of the nodule. This, as mentioned later, may explain the fact that empty cracks do not close again when the nodule becomes saturated with water.

VI. *Causes of Septarian Structure.*

We are now in a position to examine the various theories that have been advanced to account for septarian structure:

(a) *Davies's Expansion Theory.*—Expansion of the nodule during growth by the swelling of any part of the interior through the addition of new material would produce a system of cracks widest on the outside as shown in the experiments quoted. If expansion is merely the increase in size due to gradual growth, a different set of conditions arises. Dr. Davies points out that he would expect on his theory field evidence of the crowding of the layers immediately surrounding the nodule. As a matter of fact, evidence of this is abundant. At Bracebridge, I noticed that the clay contact-faces were slickensided; that incipient cone-in-cone structure was not uncommon; and I also noticed numerous examples of distortion of the lamination planes in the vicinity of a concretion. Todd, in the papers already quoted, draws attention to the same phenomena in American strata. Moreover, a belt of cone-in-cone clay is noticed surrounding several septarian boulders on a New Zealand beach,[1] although they are apparently not *in situ*.

It would be well to examine the nature of the stresses thus set up and their competency to produce septarian cracking. The crowding of the strata during growth implies external pressure upon the nodule, and although this is unknown, it may possibly reach a great magnitude. The case then becomes that of a thick spherical shell subjected to external pressure. An analysis of the stresses is unnecessary, but the general results may be seen in fig. 2.[2] On any element in the shell there is a radial pressure depending on the dimensions and the external pressure, and a circumferential or 'hoop' tension. In general the intensity of the hoop tension is greater than the intensity of radial compression. Moreover, judging by the behaviour of building stone, portland cement, and other material resembling the nodules, these will possess greater resistance to compression than tension. In other words, when the limit is reached, the material will be likely to give way by tension along such

[1] A. Hamilton, Trans. New Zealand Inst., 1901, vol. xxxiv, pp. 447–45. G. A. Mantell, Proc. Geol. Soc., 1850, vol. vi, p. 319 and figure.

[2] For a general analysis see A. Morley, Strength of Materials, London, 190 pp. 293–297.

a surface as *OA*. This does not mean that a crack will open along *OA*—if it did we should expect it to widen outwards where the maximum tension exists. It means rather that the nodule would collapse; cones such as *OAB* sliding over one another. An interesting nodule shown in Plate XI, figs. 4, 5, 6, is doubtless a case of collapse by pressure.[1] A portion of the surface such as *a* has been forced in, whilst the other portions such as *b* have slipped outwards. With regard to the other phase of the expansion theory as set forth by Todd—namely, that the addition of material to the free surface of a growing nodule sets up internal stresses—I am in agreement with Crook that it is no more competent to do so in a nodule than in a growing crystal.

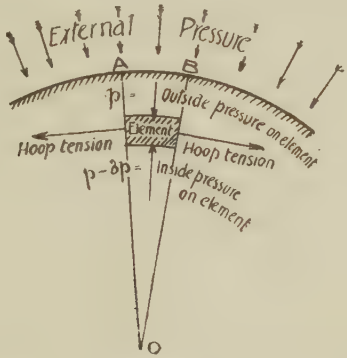

FIG. 2.—Stresses in a thick shell under external pressure.

(b) *Contraction Theories.*—These have been admirably summarized by Dr. Davies in the paper quoted, and whether contraction of the whole towards the centre is emphasized, or shrinkage on a rigid outer shell, they all look to drying as the cause of contraction. Todd[2] has criticized this theory not only on the score of uniform composition of the nodule, which I have already answered, but points out that these nodules often occur in a wet rock and are full of water themselves. Moreover, the presence of the calcite veins points to the presence of solutions since the cracks were formed. In place of the above I suggest *chemical desiccation* as the cause of the structure. This may now be examined.

(c) *Chemical Desiccation Theory.*—I do not regard either contraction

[1] I have to thank the Rev. A. Thornley and Miss Andrews for bringing this interesting and critical example to my notice.

[2] J. E. Todd, Bull. Geol. Soc. Amer., 1903, vol. xiv, p. 359.

of the interior towards the centre, or its shrinkage on an external shell as a true description, except in a few exceptional and limiting cases. They are both special cases of general desiccation due to the nature of the boundary. The stresses set up in drying are readily understood. There is contraction towards certain centres such as *A*, fig. 3. This produces tension at surfaces such as that of which *BC* is a trace. The contractile force set up in the medium towards *A* is proportional to the volume involved and also probably to the rate and conditions of drying, and depends also on the nature of the medium; whilst the tensile stress is proportional to the area of the surface and, at the fracture point, to the resistance of the medium. The size of the polygons produced is, therefore, dependent on the nature of the medium and the physical conditions of desiccation. At the boundary, the contraction is not balanced, and there results

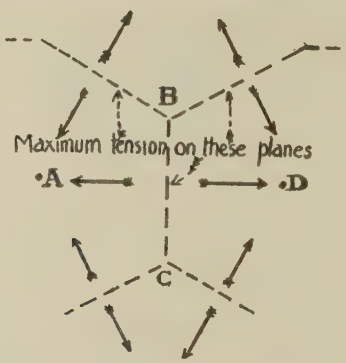

Fig. 3.—Desiccation stresses.

a certain amount of free energy, which, in the case of clay films, results in the bending inwards of the sides (Plate XI, fig. 3).

In Meunier's experiments,[1] he states that this force was sufficient to fracture 1 mm. glass. It is possible that this may have been the cause or a contributory factor to the collapse of the nodule just discussed, although the nature of the breakdown suggests that the explanation already given is the more likely. A further example of this contractile force is furnished by some Bracebridge nodules where large enclosed specimens of ammonites (*Amaltheus margaritatus*) are cracked across in the same way as the matrix.

That the cause of the drying may have been physico-chemical is rendered probable not only by the above experiments, but also by the

[1] S. Meunier, loc. cit.

fact that the existence of the nodule is evidence of the presence of strong and even supersaturated solutions. Under the conditions of temperature and pressure that obtain in a rock, and with a large time factor, chemical desiccation may proceed to limits not attainable in a laboratory. A criticism of Todd's is interesting in this connexion, namely, that the nodule in water does not swell up and close the cracks. It is possible that the colloidal nature of the original rock has been destroyed by the chemical desiccation, and, as in the case of the dried peat, is incapable of recovering that state again. Moreover, I think there has been a certain cementation of the matrix by compounds of iron or lime. This would not merely destroy the colloidal state, but at the same time might cause further contraction; although, as Todd remarks,[1] there are no reliable data on this point. I am also convinced, as mentioned above, that there has been a removal of certain substances in solution, and this might well be a contributory cause to contraction. In discussing this subject Mr. W. E. Howarth remarked to me that the Lias clay at Whitby under the action of sea-water did not break down and become plastic as in quarries inland, but even boulders on the beach remained as hard as rock. I made some inquiries as to the action of sea-water on clay, but, through the lack of opportunity to examine the matter on the spot, I have been unable to arrive at a definite conclusion. Such clays, however, are often badly cracked.

VII. *The Filling of the Cracks.*

The filling of the cracks is undoubtedly subsequent to their formation, as shown by the following facts:

1. Some nodules (good examples can be seen in the Mineral Gallery, British Museum) show the cracks without any infilling or with just a layer of crystals lining the walls. There is every stage from the empty to the completely filled crack.

2. Under the microscope, the structure is that of an ordinary vein—namely, fibrous crystals lining the walls with equidimensional grains infilling the centres of wider cracks. In the drusy centres of partially infilled spaces the crystals have well-developed faces.

3. The system of cracks in the empty nodules is the same both in size and character as in the completely filled nodule.

4. There is evidence to show that the exterior of the nodules is permeable to diffusing solutions. On the tip heaps at Bracebridge, for example, there is abundant evidence of a passage of iron outwards from

[1] J. E. Todd, loc. cit., 1903, p. 360.

the centre of the weathered nodules. The dried nodule is also fairly porous, as shown by its soaking up coloured fluid.

The vein material is usually calcite, but pyrites in ironstone nodules is not uncommon, although it rarely fills the larger cracks. This is no doubt deposited by the reaction of organic by-products such as hydrogen sulphide with infiltrating bicarbonate of iron solution. Barytes and other minerals are also occasionally found as vein material.

VIII. *Rhythmic Deposition.*

Field evidence strongly suggests that Liesegang's diffusion theories[1] are, as in the case of flint, applicable to the formation of these concretions. In the first place it may be noted that in accordance with Liesegang's law of form[2] these concretions tend to be spherical or sub-spherical. The sub-spherical form is due to the greater ease either of diffusion or of growth along bedding planes—a fact that has long been recognized.[3] Again septaria occur in definite bands which recur at regular intervals, e. g. at Bracebridge[4] and at Cuffley,[5] as we might expect if the deposition followed a rhythmic law. Strong evidence on this point would be obtained if the distributions of the concretions in any one band could be ascertained, such, for example, as the arrangement of the nodules in concentric circles corresponding to the deposition circles of Liesegang's plates. Unfortunately the quarry rarely exposes a floor of nodules in this way; but, by examining adjacent sections at Bracebridge, I came to the conclusion that an arrangement of this type was possible. Liesegang points out that in depositions of this sort two processes are to be distinguished :[6]

1. The formation of the material precipitated—a chemical process. In this case probably a gradual accumulation of solutions of bicarbonates by the action of the organic by-products on finely disseminated compounds of iron or lime in the rock.

2. The precipitation of the same—in general a physical process. It is to be noted that the solutions may be in the labile state or they may be precipitated by nuclei. It is commonly stated that the nuclei of these concretions are often fossils. This is not, however, borne out by

[1] For a brief account of these theories see G. A. J. Cole, Geol. Mag., 1917, dec. 6, vol. iv, pp. 64–68.

[2] R. E. Liesegang, Geologische Diffusionen, Dresden and Leipzig, 1913, chap. vi.

[3] J. Geikie, Structural and Field Geology, Edinburgh, 1912, p. 121.

[4] For the section at Bracebridge see A. E. Trueman, Geol. Mag., 1918, dec. 6, vol. v, p. 103.

[5] R. W. Pocock and L. Wells, Proc. Geol. Assoc., 1914, vol. xxv, p. 78.

[6] R. E. Liesegang, loc. cit., chap. x, Rhythmische Fällungen.

careful examination in the field. At Bracebridge, for example, whilst there are some remarkable examples already alluded to where large specimens of *Amaltheus margaritatus*, &c., are included in the nodules, the bulk are without fossils of any kind. Moreover, where fossils such as ammonites, brachiopods, &c., do occur they are rarely central. Their distribution in the nodule is as sporadic as in the rock itself, and they may occur partly included in the nodule and partly in the surrounding clay. Again, one layer of nodules at Bracebridge, which yielded scarcely any fossils, occurred only about three inches above a rich and well-defined fossiliferous band consisting largely of small ammonites. On the whole, I am inclined to think that these depositions are rhythmic and are precipitated from labile or metastable solutions, and that the presence of fossils has had little influence in determining the position of the bands. They do not show concentric lines of growth and are the result of continuous precipitation in a colloidal medium, although in the same quarry at Bracebridge small ironstone concentrations in the Middle Lias have concentric structure and are non-septarian.

Summary.

In this paper an endeavour has been made to establish the following points:

1. That septarian structure consists of a polygonal system of cracks corresponding to a mud desiccation structure.

2. That the cracking of the nodule is due to the desiccation of a colloidal centre by chemical means.

3. That the nodules originated by the rhythmic precipitation of solutions diffusing through a colloid according to Liesegang's laws.

Finally, in addition to acknowledgements made in the text, I beg leave to thank Professors H. H. Swinnerton and C. H. Bulleid for helpful criticism; Mr. H. Preston for placing his collection at my disposal; the chemical staff of University College, Nottingham, for generous assistance; and Dr. G. T. Prior for his kind attention at the British Museum.

Explanation of Plate XI.

Fig. 1.—Typical septarian nodule from the Lias of Nottinghamshire, showing a concentric line at *a*. The original 6 inches in diameter (p. 328).

Fig. 2.—Ironstone nodule from Bracebridge, Lincolnshire, showing a large concentric crack. Original 6 inches in diameter (p. 328; analyses of the inner and outer portions on p. 331).

Fig. 3.—Film of Reading clay on glass plate dried in air, showing polygonal cracks, which decrease in width towards the glass boundary where contraction is restrained, and imitating septarian structure (p. 330).

Figs. 4–6.—Collapsed limestone septarian nodule from Nottinghamshire: fig. 5, the nodule viewed from above; fig. 4, vertical section through XX; fig. 6, horizontal section. Size 9 inches in diameter (p. 333; analysis on p. 331).

Mineralogical characters of Turite (= turgite) and some other iron-ores from Nova Scotia.

By L. J. Spencer, M.A., F.G.S.

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[Read January 14, 1919.]

THE material examined forms part of the late Dr. Henry S. Poole's [2] collection, which shortly before his death he decided to present to the British Museum. Dr. Poole was at one time Government Inspector of Mines in Nova Scotia, and his collection is rich in Nova Scotian ores and minerals from many well-defined localities. Amongst the iron-ores, the following mineral-species and localities [3] are represented:

Magnetite, massive: *Whycocomagh, Inverness Co.*
— massive, with amethyst: *Bay of Fundy.*
— crystals (110) (111): *Five Islands, Cumberland Co.*
Haematite, red, massive: *Blanchard, East River, Pictou Co.*
— red, earthy and micaceous: *East River, Pictou Co.*
— stalactitic, partly altered to turite: *Bridgeville, Pictou Co.*
— red, massive: *Torbrook, New Cannan, Annapolis Co.*
— red, massive: *Owl's Head, Halifax Co.*
— red, soft and scaly, with fluorite: *Cheticamp, Inverness Co.*
— black, massive: *Londonderry, Colchester Co.*
— fibrous, mamillated crusts; compact and earthy; and pseudomorphous after goethite (p. 345): *Old Barns, Colchester Co.*
— foliated specular-iron-ore, with quartz: *Gaysborough, Gaysborough Co.*
Turite, hard, black, lustrous, on limonite (p. 342); also soft earthy, brick-red layers on limonite and haematite: *Bridgeville, Pictou Co.*
— earthy, pseudomorphous after ankerite: *Londonderry, Colchester Co.*
Goethite [4], crystals altered to haematite, i.e. pseudomorphs of haematite after goethite (p. 345): *Old Barns, Colchester Co.*
— minute crystal scales on calcite crystals in limestone cavity: *McLean's Bank, Pictou Co.*

[1] Communicated by permission of the Trustees of the British Museum.

[2] See this volume, p. 143.

[3] Compare R. A. A. Johnston, A list of Canadian mineral occurrences. Geol. Survey Canada, 1915, Mem. 74.

[4] The British Museum collection also has a specimen of minutely crystallized, velvety goethite (var. przibramite or sammetblende), on limonite with barytes, from Bridgeville, Pictou Co.

LIMONITE, fibrous and compact, with smooth, black, botryoidal or mamillated surface, sometimes with iridescent tarnish; also earthy, with turite pseudomorphous after ankerite: *Londonderry, Colchester Co.*
— fibrous and compact, with bright, black, botryoidal or stalactitic surface, with barytes and turite: *Bridgeville, Pictou Co.*
— fibrous and compact: *Glengarry, Pictou Co.*
— compact and siliceous: *East River, Pictou Co.*
— cellular and friable: *Smith's farm, Parrsboro, Cumberland Co.*
CHALYBITE, massive, cleavable, var. sideroplesite: *Londonderry, Colchester Co.*
— small crystals closely set in a matrix of chlorite: *Bridgeville, Pictou Co.*
— massive, crystalline, coarse-grained: *Sutherland brook, Pictou Co.*
— band of clay-iron-stone: *Stellarton, Pictou Co.*
— nodule of clay-iron-stone: *Mabou, Inverness Co.*
MESITITE, pale-brown cleavage masses with ankerite: *Londonderry, Colchester Co.*
ANKERITE, pale-brown and white cleavage masses: *Londonderry, Colchester Co.*
— small twisted crystals with calcite on sandstone: *McKay's ford, East River, Pictou Co.*

My attention to these iron-ores was attracted in the first place by the pseudomorphs of haematite after goethite. These specimens were labelled goethite, but I found them to give a dark-red streak resembling that of turite; and I started work on them with the hope that the material might prove to be crystallized turite. In this I was disappointed; but as the results obtained add a few new data respecting the mineralogical characters of these ores, they are now offered for publication.

Before proceeding to a more detailed description of the particular specimens, it will be well to give in this place a few general remarks on the group of ferric hydroxide minerals. Several of these, which have been described under special names, are listed below with some of the corresponding data, haematite being added to complete the series:

		H_2O %	Sp. Gr.
Haematite	Fe_2O_3	0	5·2
Turite	$2Fe_2O_3.H_2O$	5·3	4·3
Goethite	$Fe_2O_3.H_2O$	10·1	4·2
Hydrogoethite	$3Fe_2O_3.4H_2O$	13·1	3·7
Limonite	$2Fe_2O_3.3H_2O$	14·5	3·9
Xanthosiderite	$Fe_2O_3.2H_2O$	18·4	—
Limnite	$Fe_2O_3.3H_2O$	25·3	2·8[1]
Esmeraldaite	$Fe_2O_3.4H_2O$	31·1	2·6

Of these, the only hydroxide that occurs as definite crystals is the

[1] Determination in a heavy liquid on material from Moss mine, Ranen-Fjord, northern Norway, described by J. M. Campbell, Mining Magazine, 1917, vol. xvii, p. 220.

orthorhombic goethite; but some of the others have a fibrous structure, and limonite and hydrogoethite have been described as orthorhombic from their optical characters.[1] Instead of regarding them as distinct mineral-species there is a general tendency at the present time to consider them as colloids containing water in variable amount. The name ehrenwerthite[2] has been applied to the colloidal hydrate with the composition $Fe_2O_3.H_2O$ corresponding with the crystalloid goethite, and stilpnosiderite[3] for the colloidal form corresponding to limonite. In some of the more recent text-books (e.g. those of Hintze, Lacroix, Tschermak) all these minerals, with the exception of goethite, are treated together under limonite. There does not, however, appear to be sufficient reason for this; and certainly it is not logical to include turite here, since this falls between haematite and goethite, which are the only distinctly crystallized members of the whole series. It would be preferable to include turite (then calling it by its synonym hydrohaematite) under haematite, since most earthy, red haematite contains 1–2 per cent. of water,[4] representing perhaps a stage in the alteration of haematite to turite or perhaps a mixture of the two. Reasons will, however, be given farther on for regarding turite as a distinct mineral-species.

The parallel series of aluminium hydroxides includes fewer members, and here two—diaspore and gibbsite—are distinctly crystallized:

Corundum	Al_2O_3	(corresponding with Haematite).
Diaspore	$Al_2O_3.H_2O$	(,, ,, Goethite).
Bauxite	$Al_2O_3.2H_2O$	(,, ,, Xanthosiderite).
Gibbsite	$Al_2O_3.3H_2O$	(,, ,, Limnite).
Shanyavskite	$Al_2O_3.4H_2O$	(,, ,, Esmeraldaite).

Some explanation is needed in this place for the name *turite* in preference to the established spelling turgite. The latter is based on an incorrect German transliteration from the Russian, and was afterwards changed by its author, R. Hermann,[5] to Turjit. The mineral was origi-

[1] A. Lacroix (Minéralogie de la France, 1901, vol. iii, p. 360) also makes out a distinction between the optical characters of goethite and its scaly variety lepidocrocite; for the latter he suggests the composition $5Fe_2O_3.6H_2O$ or $4Fe_2O_35H_2O$.

[2] F. Cornu, Zeits. Prakt. Geol., 1909, vol. xvii, p. 82.

[3] A. Lacroix, loc. cit., p. 366; F. Cornu, 1909, loc. cit.

[4] H. W. Fischer, Zeits. Anorg. Chemie, 1910, vol. lxvi, p. 48.

[5] R. Hermann, Bull. Soc. Nat. Moscou, 1845; vol. xviii, No. 1, p. 252, 'Ich habe den Namen Turgit nach dem Flusse Turga, in dessen Nähe sich die berühmten turginskischen Kupfergruben bei Bogoslowsk, wo sich dieses Mineral vorfand, befinden'. R. Hermann, Heteromeres Mineral-System, Moskau und Leipzig, 2nd edit., 1860, p. 81.

nally found in the Turinsky mines at Turinsk, near Bogoslovsk in Govt. Perm, Urals; and was named, like the village and the mines, from the adjoining Turya (Turia, Turja, Турья) river. J. V. Samoilov[1] gives the name in Russian as Турьитъ (i.e. turite), and writing in German as Turjit; these two forms are, however, not exactly equivalent.

Turite and Limonite from Bridgeville, N. S.

The specimen (B.M. 1917, 120) which was examined in detail consists of a mass of hard, dark-brown to black, mamillated limonite, on the surface (normal to the fibres) of which is a layer of turite about 1 cm. in thickness. The two minerals are quite distinct in character and show a perfectly sharp line of demarcation, along which they can be broken apart. The turite forms the exterior mamillated surface, and beneath it is a mamillated surface of limonite. The turite is black with a brilliant, pitchy to sub-metallic lustre. In a strong light, in certain positions, it shows a deep reddish tinge of colour. There is a columnar structure perpendicular to the surface and a fine concentric banding parallel to the surface.

A plane surface was cut and polished normal to the junction of the two minerals. The turite takes a much higher polish than the limonite; and on the polished surface the wavy concentric banding is brought into prominence with little indication of the fibrous structure. The limonite, on the other hand, shows the fibrous structure more prominently than the concentric. Included in the limonite area are a few narrow veins and spots that have taken the higher polish: these presumably consist of turite. A thin micro-section, cut normally to the junction and including both minerals, shows that the narrow concentric bands of turite are separately built up of short fibres or rods arranged normally to the surface. In a strong light it transmits a deep crimson colour for vibrations parallel to the length of the fibres, whilst for vibrations perpendicular to this direction it is almost opaque; the material is thus strongly pleochroic. Between crossed nicols it extinguishes uniformly parallel to the length of the fibres. The limonite in thin section shows a pronounced plumose arrangement of its fibres, and in places it forms spherulitic structures. This mineral is much more transparent, and is of a rich brownish-yellow colour. Pleochroism is scarcely perceptible, but the greatest absorption is here also for vibrations per-

[1] J. V. Samoilov, Bull. Soc. Nat. Moscou, 1900, n.s. vol. xiv (for 1899), p. 142; J. V. Samoilov, Die Turjiterze Russlands. Zeits. prakt. Geol., 1903, vol. xi, p. 301.

pendicular to the length of the fibres. The extinction is uniform and straight. Both minerals, when fragments are crushed in oil on a microscope-slide, break up into short stumpy fibres, which show the optical characters described for the thin section.

The streak of the turite is dark cherry-red, and of the limonite yellowish-brown. The turite is harder ($H = 6\frac{1}{2}$) than the limonite ($H = 6$), but it is more brittle, breaking concentrically as well as radially: the limonite is tougher and breaks only radially. Specific gravity of the turite $D_4^{22} = 4{\cdot}35$, of the limonite $D_4^{22} = 3{\cdot}87$.

When heated in a bulb-tube the two minerals give off water, but otherwise their behaviour is quite different. At a low red-heat turite

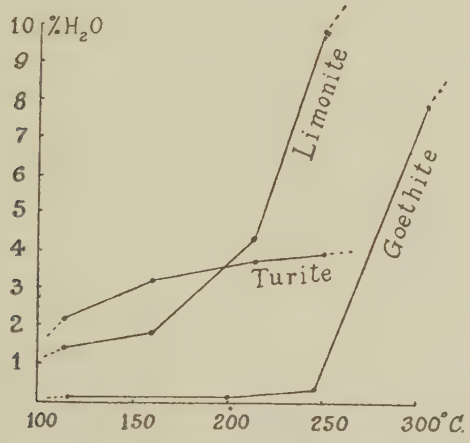

Fig. 1.—Dehydration curves of Turite, Limonite, and Goethite.

suddenly decrepitates with surprising violence, hot fragments being shot out of the tube, and the piece of material is broken up into a heap of minute fibres with a purplish-black colour. Water is given off both before and after the decrepitation. Limonite, on the other hand, gives off its water quietly and without breaking up: it changes to black in colour. The percentage loss of water at various temperatures was determined under identical conditions for the two minerals. The finely powdered material, about 1·5 gram of each, was heated in two crucibles placed side by side in an air-oven, and finally over a Bunsen-burner. Heating at each temperature was continued for one hour, and was repeated until a constant weight was attained. During the heating, the turite shows no marked change in colour, though after ignition it is rather

darker red, or purplish-black whilst still hot. The limonite changes to dark brown at 250°, and after ignition shows the same colour as the turite. The results are tabulated below; and are plotted, together with the results for goethite (p. 347), on the curve (fig. 1).[1] There is a marked difference in the character of these three curves, sufficient to indicate that the minerals are distinct and not colloidal.

	114°.	160°.	212°.	250° C.	Red heat.	Theory.
Turite	2·2	3·2	3·7	3·9	5·7	5·3 % H_2O
Limonite	1·4	1·8	4·3	9·8	13·5	14·5 % H_2O

The deviation from the theoretical amount of the total percentage of water expelled at a red-heat is to be attributed, in the case of the limonite, to the presence of admixed turite. As mentioned above, turite is visible on the polished surface of the limonite, but in selecting material for the determinations this was avoided as far as possible by picking out small fragments under a lens.

The other specimens of turite, mentioned on p. 339, are earthy in character with a brick-red to dark-red colour. Beyond determining the red streak and the presence of water, these were not further examined. When heated in a bulb-tube they do not decrepitate. They perhaps represent the colloidal form of turite.

The fibrous turite described above is without doubt a definitely crystallized mineral with the composition $2Fe_2O_3.H_2O$, and it must rank as a distinct mineral-species. This conclusion is amply confirmed by the observations of earlier authors on material from various localities. A very similar occurrence is that described by J. G. Brush[2] from the iron mines at Salisbury, Connecticut, where the fibrous, lustrous turite forms a layer, an inch in thickness, on limonite, with a sharp separation between the two minerals. This material has sp. gr. 4·14, H. $5\frac{1}{2}$, H_2O 5·02—5·20 per cent., a dark red streak, and it decrepitates in a remarkable manner. E. Manasse[3] has described similar material from Rosseto at the iron mines of Rio Marina, Elba, here also as a fibrous crust on limonite, with sp. gr. 4·34, H. 5, H_2O 4·95—5·58 per cent. The original hydrohaematite of Breithaupt,[4] from Siebenhitz near Hof in Bavaria, is also precisely similar, with sp. gr. 4·30—4·33, H. $6\frac{1}{2}$—$7\frac{1}{2}$, H_2O 4·61 per cent. Other material probably identical in character has been

[1] Similar dehydration curves may be plotted from the results given by H. W. Fischer, in Hintze's Handbuch d. Min., 1910, vol. ii, p. 2075; and Zeits. Anorg. Chemie, 1910, vol. lxvi, p. 45.

[2] J. G. Brush, Amer. Journ. Sci., 1867, ser. 2, vol. xliv, p. 219.

[3] E. Manasse, Atti Soc. Toscana Sci. Nat., 1911, Mem. vol. xxvii, p. 76.

[4] A. Breithaupt, Handbuch der Mineralogie, 1847, vol. iii, p. 846.

less completely described by P. J. Yorke[1] from Wunsiedel in Bavaria; C. F. Rammelsberg[2] from Horhausen in Rhineland; H. How[3] from Tennycape, Hants Co., Nova Scotia; P. Zemyatchensky[4] from the Melenki district, Govt. Vladimir, Russia. The original turite (turgite) of R. Hermann (loc. cit.) from the Turinsky mines, Urals, differs, however, in some respects from those above mentioned. It is compact but not fibrous, and has a much lower specific gravity (3·56—3·74); it decrepitates violently when heated; hardness 5, H_2O 5·31 per cent. J. V. Samoilov (loc. cit.) mentions turite from several Russian localities, some of which possibly belong to the more definite fibrous variety.

Summary of Characters of Turite.—Ferric hydroxide $2Fe_2O_3.H_2O$, containing 5·3 per cent. of water, and occurring as hard, lustrous, mamillated or botryoidal masses with a radially-fibrous and concentric-shelly structure. It is black with often a reddish tinge of colour, and a brilliant sub-metallic lustre; the streak is dark cherry-red. Very thin fibres transmit a rich crimson colour; they are strongly pleochroic, and are birefringent with straight extinction. Sp. gr. 4·35, hardness $6\frac{1}{2}$. Decrepitates violently when heated. It usually occurs as a layer on fibrous limonite. Synonyms: turgite, turjit, hydrohaematite.

A second, possibly colloidal, form is earthy and of a bright red colour, and does not decrepitate when heated. This includes, in part, red-ochre or red-iron-ore.

Haematite Pseudomorphous after Goethite.

A specimen (B.M. 1917, 113), labelled 'Goethite, Old Barns', consists of an aggregate of globular groups of radiating acicular crystals. These rest on a thin mamillated layer of finely fibrous haematite, which in turn is deposited on a matrix of compact and earthy haematite intermixed with some calcite. There are also one or two minute crystals of barytes, which are of later formation than the fibrous haematite. The globules present a rough crystallized surface on which the individual crystals are more or less distinctly separated, but in the interior the fibres are closely packed together. The colour is dark reddish-black, with a bright, sub-metallic lustre especially on the broken fibrous surfaces. The streak is dark purplish-red and the hardness about 4.

[1] P. J. Yorke, Phil. Mag., 1845, ser. 3, vol. xxvii, p. 268.
[2] C. F. Rammelsberg, Handbuch der Mineralchemie, 1860, p. 989.
[3] H. How, Phil. Mag., 1869, ser. 4, vol. xxxvii, p. 268.
[4] P. Zemyatchensky, Trav. Soc. Nat. St. Pétersbourg, 1889, vol. xx, Sect. Geol. Min., p. 201.

The specific gravity, determined by the pyknometer method with small selected fragments consisting of aggregates of needles is $D_4^{17} = 4{\cdot}30$.

The individual crystals are small, measuring at their free ends $\frac{1}{4}$ to $\frac{1}{2}$ mm. across; but the fibres, measured from the centre of the globules, reach 1 cm. in length. On the main surface of the globules the crystals are terminated by the basal plane (fig. 2), but in corners and spaces other terminal faces are developed. These give a wedge-shaped (fig. 3) or pointed habit (fig. 4) depending on the width of the dome face *e* (011). In their appearance and orthorhombic habit the crystals are suggestive of goethite, and the measurements obtained from three crystals on the goniometer were sufficiently good to identify the following goethite forms: *b* (010), *d* (210), *m* (110), *e* (011), *r* (311).

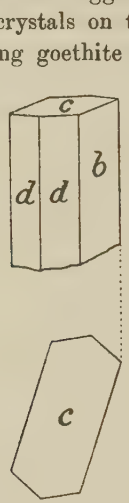

Fig. 2.

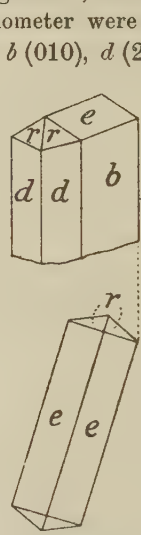

Fig. 3.

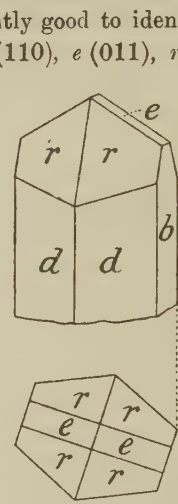

Fig. 4.

Goethite crystals from Nova Scotia.

The form *c* (001) seems to be present only on the less perfectly developed crystals. The prism-zone is deeply striated parallel to its edge, and *d* (210) is the predominating prism. The crystals readily break across perpendicular to their length, suggesting a basal cleavage, but perhaps due to a concentric banding of the material as in the turite specimen described above.

There is nothing whatever in the appearance of the crystals to suggest that they are pseudomorphs, since they are quite sharp and the faces bright and smooth; but the dark-red streak (instead of yellowish-brown) is sufficient to prove that the material is not goethite. When crushed in oil and examined under the microscope in a strong light, the

smallest particles transmit a blood-red colour. Elongated fragments, which appear to be cleavage flakes, show a greater absorption for vibrations perpendicular to their length, and between crossed nicols give uniform and straight extinction. So far as could be determined, the optical characters do not differ from those of the turite described above (p. 342); and in any case they are quite distinct from those of goethite, Cornish crystals of which were examined by the same method for comparison.

Heated in a bulb-tube the material gives off a small amount of water, but there is no decrepitation, change in colour, or breaking up of the fragments. Dehydration experiments were carried out in parallel with crystallized goethite from Cornwall,[1] about 1·5 gram each of the finely-powdered minerals being heated side by side. They remained for three days over sulphuric acid; and for one hour at each temperature.

	H_2SO_4.	117°.	200°.	246°.	304°.	Red-heat.
Nova Scotian pseudomorphs	0·1	0·3	0·3	0·3	0·3	0·65 % H_2O.
Cornish goethite	0·1	0·1	0·1	0·3	7·9	10·1 % H_2O.

The results obtained with this material were confirmed with a second specimen (B.M. 1917, 114) found without any label in Dr. Poole's collection. This is a smaller specimen with little matrix and the globular groups show to better advantage. In addition to calcite and haematite, it shows, in one cavity, a few small crystals of quartz. The specimen is so exactly similar in all its characters to the one just described that it undoubtedly came from the same locality. Two crystals were measured on the goniometer, and the same forms identified as before. Specific gravity determined on about 1·5 gram of material

[1] *Goethite from Cornwall.*—The specimen (B.M. 35384) used in the comparative experiments came from the Restormel iron mines at Lanlivery, and consists of radiating groups of crystals associated with psilomelane and quartz. They are black with a brilliant sub-metallic lustre and give an ochre-yellow streak. Specific gravity, $D_4^{20} = 4{\cdot}18$. Crushed in oil under the microscope the material shows clear brownish-yellow cleavage flakes, which are slightly pleochroic, the colour being yellow for vibrations parallel to the *c*-axis, and brown for vibrations perpendicular thereto. The extinction is straight; optic axial plane parallel to (001), acute negative bisectrix perpendicular to the cleavage *b* (010); optic axial angle in air 2E = 60° about, the brushes being brightly coloured owing to the high dispersion. Heated in a bulb-tube, the material gives off much water, but does not decrepitate or break up. Crystals that had been heated to redness did not appear to be affected in any way, the faces still being as bright and smooth as before; but they now give a dark purplish-red streak. The powdered mineral had changed from ochre-yellow to dark brownish-red at 304° C.

crushed to separate fibres, $D_4^{20} = 4{\cdot}26$. The loss of water from the finely-powdered material amounted to only 0·1 per cent. for temperatures up to 240° C., and 0·5 per cent. at a red-heat.

The material is thus practically anhydrous ferric oxide corresponding with haematite; but in its specific gravity, colour of streak, and perhaps also optical characters, it agrees with turite; whilst the external form of the crystals is that of goethite. The only conclusion to be drawn from these observations is that the material represents pseudomorphs of haematite after goethite. The crystals themselves are, however, so unlike pseudomorphs that I still had some doubt as to the correctness of this, until I noticed that the bright crystals of Cornish goethite preserved their sharpness and freshness after being heated to redness (p. 347, footnote). These are, in fact, exactly similar pseudomorphs of haematite after goethite, but produced by artificial means. The Nova Scotian specimens show no signs of having been heated artificially; and, besides, the presence of calcite would preclude this, since the water of goethite is lost only at a red-heat. It is certainly a remarkable fact that the crystals can lose 10 per cent. of their weight without being visibly affected. In this connexion it may be noted that the specific gravity of the pseudomorphs (4·3) is only slightly greater than that of goethite (4·2), but considerably less than that of haematite (5·2); its identity with that of turite (4·3) is probably only an accidental coincidence. Pseudomorphs of haematite after goethite have already been described by Haidinger[1] from Cornwall, and he mentions that the fine brilliant crystals were measured by G. Rose. These were, however, possibly artificial, since Greg and Lettsom[2] mention that some specimens of Cornish goethite were strongly heated by dealers with the idea of passing them off as rutile.

Since the above was written, several other specimens of turite, exactly similar to the one described on p. 342, have been found in the Poole collection. These I had incorrectly put aside as duplicates of limonite, which superficially they closely resemble in appearance.

[1] W. Haidinger, Abhandl. Böhm. Gesell. Wiss. 1847, ser. 5, vol. iv, p. 480.

[2] R. P. Greg and W. G. Lettsom, Mineralogy of Great Britain and Ireland, 1858, p. 254.

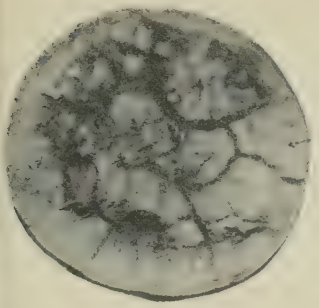

Fig 1.

Fig. 2.

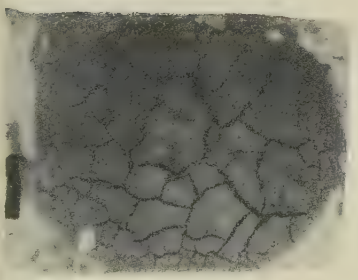

Fig. 3.

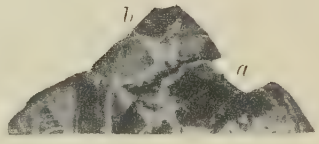

Fig. 4

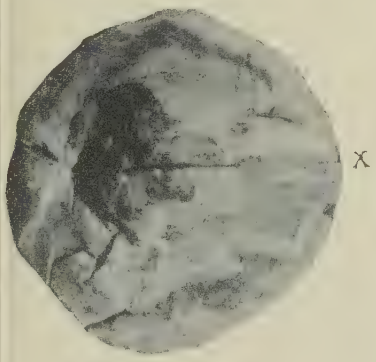

Fig. 5.

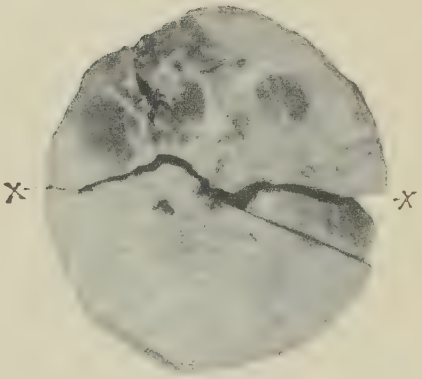

Fig. 6.

W. A. Richardson: Septarian Structure.